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INDO-PACIFIC FISHERY COMMISSION

PAPERS CONTRIBUTED TO THE WORKSHOP ON THE USE OF CYPRINIDS IN THE FISHERIES MANAGEMENT OF LARGER INLAND WATER BODIES OF THE INDO-PACIFIC

Kathmandu, Nepal, 8-10 September 1988

and

COUNTRY REPORTS PRESENTED AT THE FOURTH SESSION OF THE INDO-PACIFIC FISHERY COMMISSION WORKING PARTY OF EXPERTS ON INLAND FISHERIES

Kathmandu, Nepal, 8-14 September 1988

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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edited by

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PREPARATION OF THE DOCUMENT

This document is the supplement to the report adopted on the 14 September 1988 by the participants in the Fourth Session of the Indo-Pacific Fishery Commission Working Party of Experts on Inland Fisheries, Kathmandu, Nepal, 8-14 September 1988. The supplement contains two types of edited documents: Part One - papers presented at the Workshop on the use of Cyprinids in the Fisheries Management of Larger Inland Water Bodies of the Indo-Pacific (8-10 September 1988); and Part Two - Country Reports (China, Nepal, Sri Lanka).

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ABSTRACT

This publication contains all documents presented at the Fourth Session of the Indo-Pacific Fishery Commission Working Party of Experts on Inland Fisheries, held in Kathmandu, from 8 to 14 September 1988. Part One consists of 11 papers contributed to the Workshop on the Use of Cyprinids in the Fisheries Management of Larger Inland Water Bodies of the Indo-Pacific, held 8-10 September 1988. Part Two presents three country reports: China, Nepal and Sri Lanka.

The Workshop has highlighted the similarities and differences in cyprinid significance, not only among the various countries in the region, but also among different areas within each country. In countries or geographical areas west of the Wallace line (e.g., India, Nepal, Thailand, China and western parts of Indonesia), cyprinids occur naturally and are of high fisheries importance. In contrast, cyprinids are naturally absent in countries or geographical areas east of the Wallace line (e.g., Papua New Guinea and the eastern parts of Indonesia like Sulawesi and Irian Jaya), which therefore have cyprinid fisheries based only on introduced species. High yields have been reported for lake-associated pen and cage culture of bighead carp in the Philippines, and medium yields have been obtained in the high-altitude/ mountain lakes of Irian Jaya. In Sri Lanka, the exotic carps have made some impact in some medium-sized reservoirs and have been shown to be suitable for fisheries management of seasonal tanks.

Cyprinids constitute the dominant group of fish in most of the countries represented at the Workshop and as such, make the best tools for fish yield enhancement. Stocking of carps has been recognized as a tool in increasing and sustaining fish yields in large water bodies in most IPFC member countries. Fast-growing, large-sized species of Indo-Gangetic and Chinese origin are generally preferred for the following reasons: (i) they occupy all the trophic levels in reservoirs and lakes and lead to good fisheries; (ii) they supplement poor stocks and supplant inferior species; (iii) their use in culture-based reservoir fisheries as well as in pen and cage culture could be profitable.

CONTENTS

		Page
PART ONE:	Papers contributed to the Workshop on the Use of Cyprinids in the Fisheries Management of Larger Inland Water Bodies of the Indo-Pacific	1
PART TWO:	Country reports: China, Nepal and Sri Lanka	155

PART ONE

Papers contributed to the Workshop on the Use of Cyprinids in the Fisheries Management of Larger Inland Water Bodies of the Indo-Pacific
Kathmandu, Nepal, 8-10 September 1988

CONTENTS

Page

1. The use of common and Asian carps in the fisheries management of larger inland water bodies of the Indo-Pacific, by T. Petr 1
2. Fish stock enhancement in larger Indo-Pacific inland water bodies using carps and tilapias, by A. Sreenivasan 6
3. The trends of the Sri Lankan reservoir fishery wih special reference to the role of cyprinids, by S.S. De Silva 34
4. Gobindsagar reservoir: a case study on the use of carp stocking for fisheries enhancement, by K. Kumar 46
5. The use of carps in the fishery management of reservoirs and lakes in Indonesia, by Atmadja Hardjamulia and N. Sweta Rabegnatar 70
6. Status of Schizothorax species in the Indian-Chinese sub-continent, by B.P. Sharma 90
7. Katle (Acrossocheilus hexagonolepis), a cold-water cyprinid of Nepalese waters, by A.K. Rai and D.B. Swar 95
8. A review of the utilization of carps in inland fisheries management in the Philippines, by Elvira A. Baluyut 100
9. The use of common carp and Asian carps in the fisheries management of larger inland water bodies in Sri Lanka, by A.M. Jayasekara 114
10. The use of cyprinids in fisheries management of the larger inland water bodies in Thailand, by Thiraphan Bhukaswan 142
11. Summary review of common carp, Cyprinus carpio L., in Papua New Guinea, by D. Coates 151

THE USE OF COMMON AND ASIAN CARPS IN THE FISHERIES MANAGEMENT OF LARGER INLAND WATER BODIES OF THE INDO-PACIFIC

by

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The use of cyprinids, i.e. mostly carps to enhance fish yield in larger inland water bodies, that is reservoirs and natural lakes, has been practised in a number of countries of the Indo-Pacific, with mixed results. For some years the hatchery technology of mass production of carp fry for stocking has been widely used with a high rate of success. Excellent new manuals have been produced (FAO, 1985, 1985a; Jhingran and Pullin, 1985). The widespread use during the last two decades of Chinese-type hatcheries has speeded up mass production of fry. FAO, in collaboration with Hungary, organizes annual training courses in aquaculture, with much attention paid to carp production. There is a long tradition in carp production in mono- and polyculture, and in integrated aquaculture in small water bodies. A number of projects have been executed by FAO in many countries of Asia on carp production, involving especially establishment of hatcheries, polyculture and integrated aquaculture.

The percentage proportion of cyprinids in the total fish yield from larger inland water bodies in the Indo-Pacific varies from country to country. The percentage may be high in the mainland countries of Asia, but due to their zoogeographical distribution it may be nil to very low on islands, unless exotic cyprinids, especially carps, are introduced. If native cyprinids are present on islands, they may be underutilized due to preference for other native species or even introduced non-cyprinids (e.g. tilapias in Sri Lanka). Among the exceptions is Lake Lanao in Mindanao, Philippines, which has a group of 17 species of endemic cyprinids. These formed the basis of a fishery until recently. Both the countries lacking or having a low number of endemic cyprinids, and those with relatively high numbers of cyprinid species, have introduced exotic cyprinid species to enhance their capture fisheries. An inventory of fish species with potential for enhancing fish production in lakes and reservoirs of tropical and subtropical countries of the Indo-Pacific (Petr, 1988), based on answers to a questionnaire from only 7 countries, and therefore not necessarily a representative sample of the Indo-Pacific, puts forward 15 cyprinid species as suitable for yield enhancement. Other fish families are represented by 17 species, including two species of cichlids. It should be pointed out that Australia, one of the seven countries, does not recommend a single cyprinid for enhancement, as their inland fishery is almost entirely for sport purposes, and because carps are traditionally considered not acceptable as food by the majority of Australians. If Australia is not considered in the above sample, the remaining six countries (India, Indonesia, Nepal, Philippines, Sri Lanka, Thailand) recommend 14 cyprinids and 8 non-cyprinids (of these, two species of tilapias), which shows the high preference given to cyprinid representatives by countries which aim at increasing the fish yield for food consumption purposes.

In some countries, e.g. India, Thailand, Pakistan, Sri Lanka and Indonesia, hatchery-produced seed of selected cyprinids is stocked into reservoirs and lakes to enhance their fish yield. This was considered essential especially in reservoirs established on rivers which had strong carp populations (e.g. Indo-Gangetic system), but now, as a result of damming and subsequent permanent submergence of floodplains where cyprinids spawn, there has been a drastic decline in cyprinid fish stocks. In India a drastic decline of endemic carps in the Cauvery River system was reported after the construction of Stanley and Bhavanisagar dams. Sreenivasan (1986) reported that this loss was more than compensated for by the transplantation of Gangetic carps. In China, stocking common carp, grass carp, silver carp, bighead carp, mud carp and Wuchan fish (*Megalobrama amblycephala*) gives valuable returns: in some reservoirs nearly 60% of fish stocked may be recovered (returns of 50% are regarded as excellent, 10-30% as good, less than 10% as poor). Annual yield averaged 113 kg/ha (in 1983) which is about two thirds of that reported from lakes managed in the same way (Li, 1988).

In Sri Lanka, selected seasonal tanks (less than 80 ha in surface area), which store water for 6 to 10 months of the year, are regularly stocked with exotic Indian major carps, Chinese carps, tilapias and the indigenous carp *Labeo dussumieri*. A yield of 372 kg/ha is quoted for 1984/85 (Beveridge and Philipps, 1988).

In Indonesia, common carp is the most important species cultured in reservoirs (Hardjamulia and Suwignyo, 1988). In Saguling Reservoir, floating net aquaculture showed that protein production of a single cage of $17\ m^3$ (7x7 m) stocked with common carp, is sufficient to supply 61% of the protein need of a family of five persons for one year (Costa-Pierce *et al.*, 1988).

As might be expected, yields of carps stocked into free water are of larger reservoirs and lakes are highly variable, both between reservoirs (in China from less than 50 kg to more than 1 500 kg/ha) and between years, as a result not only of geographic location, weather and differences in productivity, but also of differences in stocking rate, reservoir size, management (feeding, fertilizing, fishing pressure and fishing techniques) and the presence of predatory fish.

There is still a poor understanding of conditions which lead to optimal carp production in larger water bodies. As indicated above we seem to know more about semi-intensive and intensive carp aquaculture using pens and cages positioned in such water bodies than about the actual carp production in open waters. Little is known about cyprinid interactions with other fish, the optimal fish species set up for a particular water body, the rate of stocking required in such water bodies, the significance of repeated stocking, optimal size of stocked fingerlings and their rate of survival; and with the exception of China, India and Thailand, detailed statistics are mostly unavailable. We know little of the relationship between the overall aquatic productivity parameters such as conductivity, phytoplankton-zooplankton density, primary production, carbon content in sediments and/or water column, macrophyte cover, littoral extent, and of requirements of cyprinids for submersed plants to achieve optimal yield. In other words, we do not know how to use the accumulated data bases on a great variety of physico-chemical and biological factors for determining the future cyprinid production, and where stocking is necessary, the numbers of fingerlings to be stocked. Interactions among cyprinid species, that is their competition for niches and for food where fish is regularly stocked as fingerlings produced in hatcheries, are poorly known or unknown. This concerns especially interactions between the Chinese and Indian carps and the common carp. Another grey area is the interaction between carps and crayfish and freshwater prawns.

Without such knowledge, suggestions for improvement are difficult to make. We need to know more about efficient harvesting methods which would allow us to harvest most of the stocked fish from large water bodies with regular stocking programmes. Two major carp growers in Asia, i.e. India and China, have the most experience in the Indo-Pacific with regular stocking and harvesting of larger water bodies, with steady improvements in methods and the knowledge of factors which are behind maintaining sustained high yield from such water bodies. These two countries could undertake the task of compiling all relevant data on the subject, analyse them for relationships and identify the factors behind high sustained yields, and make them available to other interested countries. There may already be available a sufficient number of well documented case studies for construction of simple predictive models, based on simple relationships between easily measurable factors. While the morphoedaphic index (MEI) has been widely used for a number of years for predicting fish yield for African water bodies, this index still needs to be tested in depth in Asia. It could be tested selectively for homogeneous geographical areas, such as for example: water bodies of semi-arid India and Pakistan, Sri Lanka reservoirs, Thai reservoirs, Indonesian reservoirs. It could also be tested on a large relatively homogeneous group of fish such as carps. Relationships such as between fish yield and primary production, or fish yield and organic matter content, should also be tested to see whether they could be used for yield prediction.

Another aspect which we should try to understand better is the coexistence of carps and tilapias in the same water body. Tilapia and common carp, both exotic species for Papua New Guinea, are now spreading through the Sepik River basin catchment, apparently with little competition from each other or from the endemic species. We need to evaluate them for their mutual relationships, competition, yield, and also for their marketability.

The economics of stocking tropical water bodies with cyprinids also needs to be assessed, especially for water bodies which have their own stocks of other fish, which may be perhaps cheaper to produce or harvest. The economics of stocking reservoirs with larger sized fingerlings in an effort to improve recovery rates in the face of high predation pressure needs to be evaluated. In China, experiments have indicated that one 13.2 cm fingerling provides a stocking efficiency equivalent to that provided by three 10 cm fingerlings or twelve 7 cm fingerlings (Li, 1988). The 13.2 cm stocking size is not only biologically, but also technologically profitable from the point of view of fry and fingerling production. In Fujiaohe Reservoir, stocked with bighead and silver carps, in the presence of the predator Elopichthys bambusa the yield was less than 25 kg/ha, while when the predator was absent the yield reached 420 kg/ha.

Another aspect which requires closer attention is the town market demand for expensive fish, which should be considered when programming for stocking. Such demand may inhibit the production of cheap fish as is known, for example, for some areas of India. In this region the opinion of fishermen and their interest in producing cheap fish versus expensive fish should also be taken into consideration. The socio-economics of cyprinids versus other fish needs to be looked into.

The impact of eutrophication on cyprinid versus other fish production should also be looked into. Reservoirs and lakes in Asia and the Pacific are gradually increasing their nutrient load derived from their cultivated catchments, from the increasing inputs of fertilizers, soil erosion and human settlements. It needs to be evaluated whether such encroaching eutrophication is beneficial to carps, and what its impact is on fish other than carps sharing the same water bodies.

These are some of the issues which require more attention. Cyprinids, as a fish family, are an important group of fish in larger water bodies of the Indo-Pacific countries, and of considerable significance for animal protein production. Enhancement of their stocks is among the priorities of many governments. This Workshop should highlight their present importance for inland fisheries and propose what future steps are necessary for further enhancement of cyprinids in larger water bodies of the Indo-Pacific.

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FISH STOCK ENHANCEMENT IN LARGER INDO-PACIFIC INLAND WATER BODIES USING CARPS AND TILAPIAS

by

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1. INTRODUCTION

The fishery yields from large reservoirs in the Indo-Pacific region vary from a very low to moderate level. Fernando (1977) has tabulated the yields from some of the reservoirs, lakes and ponds in this region giving an average of about 20 kg/ha/yr for 3 million ha of water spread. Some yields are rather low, and fishery managers have considered increasing them by stocking. In some situations, with no suitable native species available, it has been necessary to introduce an exotic species. Stocking and introduction of fish in lakes and reservoirs in the Southeast Asian countries has been reviewed by Bhukaswan (1980) and for India by Sreenivasan (1984), the latter author stressing the need of taking into account market prices and consumer demands when considering stocking. Fernando (1977, 1980) and De Silva and Fernando (1980) have been advocating the stocking of African cichlids to enhance production, based on the experience in Sri Lanka. Since then, and especially from 1983, it has been possible to breed the Indian major and Chinese carps by hypophysation in Sri Lanka. This has somewhat altered the situation from the one encountered by Fernando (1980) and has led to revival of the idea of the suitability of carps for selected water bodies in Sri Lanka.

The fish yields in some better known reservoirs and lakes of the IPFC region are presented below.

2. FISH YIELD ENHANCEMENT IN SELECTED ASIAN COUNTRIES

2.1 India

Bhavanisagar Reservoir (Tamil Nadu):

Catla: From 1954-55 to 1979-80, 450 935 fish were stocked, and the yield was 207 661 kg. From 1980-81 to 1987-88, 1 136 687 were stocked and the yield was 56 329 kg . For the whole period a total of 1 587 622 Catla was stocked and 263 990 kg harvested. Recapture varied from 8.2 to 27.4% of the total catch by weight. Lower recaptures of Catla coincided with the increased catches of tilapia. The cost of stocking was about Rs.400 000, while the value of the catch was Rs.2.6 million. This pertains only to Catla.

Rohu: The performance of rohu has been unsatisfactory. Despite the higher rate of stocking than Catla, the recapture has been insignificant (0.6 to 11.8% of the total catch). It is not clear whether the poor performance of rohu was due to the great success of Labeo calbasu which dominated the catches (see below).

Mrigal: When stocked in reasonable quantities the recapture has been good. From 1970-71 till 1977-78, mrigal represented over 10% of the total catch. In spite of the good stocking during 1977-78 and 1978-79, the catches were poor till 1982-83. Since 1984-85 the recapture has been high (19.9% in 1984-85 and 19.3% in 1986-87).

Labeo fimbriatus: This indigenous major carp does not tolerate well the changed ecological conditions after the damming of the river. Since 1963-64, the catches have been very poor and stocking did not result either in any catch at all for the period 1968-69 to 1972-73 or in negligible catches later on (less than 2% of yield). Stocking of this species therefore does not look promising.

Cirrhinus cirrhosa: This major indigenous carp has not appeared in the catches since 1962-63 and subsequently, despite stocking of 265 085 fingerlings over two decades. Like L. kontius and L. fimbriatus, this species should be relegated to the riverine portion.

Labeo calbasu: This is a trans-basin introduction which has immensely benefited the reservoir fishery. The yield was 12.0% in 1965-66, and later on it rose to over 30% and remained at that level till 1981-82, reaching a peak of 46.7% in 1978-79. A substantial fishery was established for this species, which seems to have adjusted itself to the reservoir lacustrine conditions. Stocking had no relevance because there was a massive natural recruitment of this species based on the existing stocks. Since 1983-84 there has been a decline in this fishery which has coincided with a reduced predator population, but with significantly increased tilapia and Puntius sarana populations.

Cyprinus carpio: Introduction of the German strain (mirror carp) as well as the Bangkok strain (common carp) was a total failure. Out of 65 857 mirror carp stocked, only 8 were recovered. Out of 605 920 common carp stocked between 1962-63 to 1971-72, not one was recaptured. 975 320 common carp were stocked between 1972-73 and 1981-82, to yield a meagre total of 2 492 kg of fish, which proves the utter unsuitability of C. carpio for the deep, large reservoirs of southern India.

Puntius dubius: This native carp has been able to maintain itself satisfactorily until 1981-82. But, since 1982-83, the yield decreased, coinciding with increased tilapia yields.

Stanley Reservoir (Mettur Dam, Tamil Nadu):

Catla: Catla of stock size were introduced by Dr. Sundera Raj in the late twenties, before the dam was sealed. The site chosen for stocking was the Hogainakkal Falls. Until 1940, 10 172 catla were stocked. In the first commercial fishing in 1951-52, nearly 16% of the yield (106 522 kg) were catla. Cirrhinus cirrhosa yielded 55.8% of the total catch. Thus, 71.8% of the yield was from carps and only 26.8% came from four species of catfishes. A decade later, starting in 1960-61, catla increased in the catches to more than 35% for the next four years. Since the stocking has been nil during these years, catla was repopulating itself. Since 1970-71, the percentage of catla in the catches decreased to less than 6%. Mere stocking of a few thousand fingerlings cannot account for the catla fishery. In more than 35 years, 365 405 fingerlings were stocked which is less than 1/yr/ha. Recruitment failure is due to very low water levels during the spawning season during many years, precluding the short upstream migration. To offset such failure of recruitment, stocking should be undertaken. In view of the high price fetched by catla, even a 10% yield would be highly profitable (average weight over 5 kg each).

Rohu: The initial low rate of stocking produced insignificant catches until 1971-72, when 14 069 kg (5.5% of the total yield) were landed. Regular stocking has given consistently good yields. From 1972-73 till 1986-87, the yield ranged from 6.5% to 31.1% of the total catch. In one single year, 147 180 kg of rohu were caught (1973-74). In the last 15 years, 8.8 million rohu were stocked - a rate of 39 fingerlings/ha/yr.

In the last four years (1982-86), the stocking rate exceeded 100 fingerlings/ha/yr and over one million fingerlings were stocked each year. This had the desirable effect of increasing the catches. Against a stocking of 8.8 million fingerlings, a yield of 828 473 kg of rohu was obtained (recapture 10.0% by numbers in some years). The present yield is profitable.

Mrigal: This species showed up in the commercial catches, first in 1960-61, yielding 20 890 kg (5-21% of the total). However, the impact of stocking has been negligible. The highest percentage was 10.4% (42 469 kg) of the total yield when rohu had not yet appeared in the catches. Being easier to breed by hypophysation, this was the species stocked most, but the recovery was not good. In 20 years, 5 million fingerlings were stocked (17/ ha/yr). In the same period, 227 536 kg mrigal were captured. Compared to rohu, this was a very poor return. As the average size of mrigal was smaller than that of rohu, the price fetched was lower.

Labeo calbasu: This species was first noted in 1966-67 when it formed 2.4% of the catches. With continuous stocking its proportion in the catch increased. From 1969-70 until 1982-83 it has been yielding over 10% of the catch; after that its catches declined. This may be due to the increase in stocks of predatory catfish and the featherback (Notopterus notopterus). From 1967-68 to 1986-87 (20 years), 2.3 million fingerlings were stocked. The harvest was 1 098 959 kg, which is an exceedingly good return. It is obvious that stocking alone has not led to such good catches and that there must have been some recruitment. Stocking rate was 11.2 fingerlings/ha/yr. Like mrigal, L. calbasu is easy to breed and so the stocking material availability is assured. This species appears to be most suitable for large reservoirs.

Cirrhinus cirrhosa: This indigenous carp of the Cauvery system was the single dominant species till 1960-61. In 1951-52 it contributed 55.8% to the total catch. Since 1970-71, the fishery dwindled to insignificant levels. In 1985 there were signs of recovery when 49 288 kg (14.4%) of this species were caught. The stocking support is inadequate and in the absence of natural recruitment, this species is gradually declining. Stocking with induced-bred seed is needed.

Sathanur Reservoir (Tamil Nadu):

This is a carp-dominated, high yielding reservoir. The species dominance among the carps changed after the introduction of Gangetic carps. The indigenous L. fimbriatus was the dominant species (34.8%) until 1964-65.

Catla: Catla was stocked in 1957 and by 1964-65 it represented 24.0% of the total catch. From then on the catches increased and by 1970-71 it reached 78.3%. Until 1976-77 catla was the dominant fishery, yielding over 80% of the total catch. All other stocked carps, i.e. rohu, mrigal, L. fimbriatus, L. calbasu and C. cirrhosa together contributed less than 10% of the yield. The harvest of these carps did not even meet their stocking cost. However, by changing to a smaller mesh the stocked carps began to appear in the catches in substantial quantities starting in 1977-78. The dominance of catla was reduced and the other stocked species increased in the catches. Catla decreased to less than half of the total catch, starting in 1978-79 and contributed as little as 11.2% to the total catch in 1984-85. There was practically no stocking of catla until 1977-78, but a high yield was being maintained by self repopulation. Since 1977-78 low density stocking has been introduced, but this has not resulted in an increase in the catla landings.

Rohu: This major carp contributed very little to the fishery till 1977-78 when its catches rose to 16.6%, 30 107 kg of the total, which might be the result of stocking in 1974-75. Since then, in some years (1977-78, 1985-86 and 1986-87), over 500/ha/yr have been stocked, which was made possible because of the existence of a fish seed farm with a breeding centre.

Mrigal: The yield from this species like that from rohu was low due to the use of large meshed gill nets used to catch catla, but which do not catch rohu and mrigal. From 1965-66 to 1969-70 mrigal comprised over 12% of the yield. Since 1978-79, its contribution to the catch rose, reaching a peak of 40.2% in 1980-81. It displaced catla as the dominant species. Regular stocking appears to be beneficial. In some years, e.g. 1978-79, stocking rate exceeded 500/ha, which might be the reason for the high yield of 95 334 kg in 1980-81. The highest catch, viz. 237 149 kg, from the reservoir since its formation also coincided with this.

L. fimbriatus: This indigenous carp failed to sustain a fishery. During 1964-65 it contributed 35.9% to the yield and was the single major species. After that it gradually decreased and never again attained this position. Despite stocking the fishery ceased to be of economic importance. This species seems to do poorly when lacustrine conditions develop.

L. calbasu: This carp appeared continuously in the catches since 1966-67, supported by regular stocking. Catches began to increase and in 1983-84 they exceeded 18% of the total catch although the rate of stocking was rsther low, i.e. 15/ha in 1983-84, a little higher in other years, and none in many years.

C. cirrhosa: The quantity captured annually is low and the stocking history is not well recorded. There is slways shortsge of fingerlings of this species, which is induced-bred in a limited quantity, and a small amount of seed is also collected from the wild.

Common carp: This species did extremely poorly, with only 4 546 kg captured in 25 years in spite of being stocked since 1974 (14 yesrs). Stocking this species in this type of reservoirs seems to be a wasted effort.

Catfish and Puntius sarana have been increasing since 1981. However, during the same period the total catch has been declining.

Amaravathy Reservoir (Tamil Nadu):

This is a classic example of a tilapia (*Oreochromis mossambicus*) reservoir in India. It is constructed on a tributary of the river Cauvery and is rich in the number of indigenous carps: *Puntius dubius*, *Labeo fimbriatus*, *L. bata*, *P. carnaticus*, *L. kontius*, *Cirrhinus cirrhosa*, etc. The Gangetic carps, catla, rohu, mrigal, *L. calbasu*, common carp and tilapia were stocked from 1957 onwards. In 1965-66, tilapia formed 13.5% of the total yield, while the indigenous carps contributed 74.8% and the gangetic catla, mrigal, rohu and *L. calbasu* contributed 6.2%. The following year, the percentage of tilapia (*Oreochromis mossambicus*) steadily increased while the dominant native carp *P. dubius* declined to less than 2% in 1968-69 and afterwards virtually disappeared. From 1968-69 tilapia constituted more than 80% of the yield. It reached a peak of 391 805 kg (91.7% of the total)in 1984-85, which is 481 kg/ha (total yield 427 091 kg, i.e. 502 kg/ha). In the next three years the total catch declined to 20 867, 43 093 and 36 566 kg, respectively (24.6 kg/ha, 50.7 kg/ha, 43 kg/ha). The population structure also changed with tilapia decreasing to 53.1% (1985-86), 26.4% (1986-87) and 23.0% (1987-88) of the total catch. In 1985-86, the Gangetic carp and common carp represented 39.1% and the native carps 6.7%. In 1986-87, the Gangetic carps yielded 40.9%, common carp 3.9% and minor carps 23.5%. In 1987-88 the Indian major carps yielded 39.0%, common carp 3.7%, and local *L. fimbriatus* 2.2%. An encouraging sign was the appearance of the stocked silver carp - 1.0%.

Uppar Reservoir (Tamil Nadu) India:

Initially this reservoir was stocked with *Oreochromis mossambicus* (172 800 and 135 360, respectively in 1971-72 and 1972-73) and common carp (19 200 and 24 640, respectively). During 1973-74, 1974-75 and 1975-76 the percentage of common carp in the total yield was 16.5, 36.5 and 24.2, respectively which is quite appreciable. From 1980-81 to 1987-88 the share of common carp in the total catch ranged from 6.4 to 21.3%, mostly being above 10%.

Uppar is one of the very few reservoirs in which silver carp (*H. molitrix*) has been stocked. This species is doing well, giving the following yields: 4.4% (1984-85), 16.2% (1985-86) and 12.9% (1987-88). During the same period (1984-85 to 1987-88), catla represented 45.9%, 12.5%, 7.9% and 21.8% of the total yield. There is no evidence of competition between the two species. During the last few years, mrigal have been captured in sizeable quantities, 20.4% (1986-87) and 24.2% (1987-88). Tilapia dominated the catches, especially when mullets (*R. corsula*) were on the decline. Rohu and *L. fimbriatus* have not been quite successful. Stocking of catla, mrigal and common carp is considered to be successful in this reservoir.

Nagarjuna Sagar (Andhra Pradesh):

The native *L. fimbriatus* were contributing sizeable quantities to the catch from 1971-72 to 1980-81 (30.7%-18.7% of the total), without stocking. This was followed by a sharp decrease to 2.1% in 1983-84, the last year for which data are available. *L. calbasu*, also an indigenous species, contributed without stocking 4.8% to 15.9% in 1979-80. Like *L. fimbriatus*, it decreased drastically to less than 1.2% in 1983-84. Between 1971-72 and 1983-84, the total percentage of three transplanted and two indigenous carps decreased from

47.7% to 4.5% by weight while the catfish population increased from 48.2% to 93.3%. It is obvious that the pre-eminence of predatory species militates against the success of stocked as well as indigenous carps. The remedy lies in drastic eradication of catfishes with simultaneous stocking of major carps in adequate numbers and size, enabling the latter to assert themselves in the fishery.

Stocking common carp in this catfish-dominated reservoir is considered futile. Not a single specimen was caught although 368 254 fingerlings were stocked. Only in one year (1971-72) the contribution of catla to the fishery reached 5.6%, usually being less than 2% of the total catch. Stocking of 5 150 rohu fingerlings resulted in a catch of only 10 890 kg. This corresponds to 53 fingerlings stocked to obtain 1 kg of rohu, or only one out of 106 stocked rohu were recaptured. In terms of percentage it was 0.4% to 2.7% of the total catch. The performance of mrigal was the worst among the three transbasin transfers. After stocking 889 134 fingerlings only 8 592 kg of mrigal were caught. To obtain 1 kg of mrigal, 103.5 fingerlings had to be stocked. Only one out of 150 fingerlings stocked were recaptured.

Vallabh Sagar (Ukai), (Gujarat):

Major carps, catla, rohu and mrigal were stocked at rather low rates ranging from 1.8 to 35.6 fingerlings/ha/yr. The yield has been disappointing and ranged from 1.45 to 3.99 kg/ha/yr. The catch composition, however, is very satisfactory. Since 1975-76 the percentage of catla has been gradually increasing, reaching 80.9% in 1982-83; the percentage of rohu considerably decreased, while mrigal maintained its strength. As is to be expected, by 1982-83 mahseer (Tor sp) virtually disappeared. In the absence of perceptible numbers of predatory species, the stocked Gangetic carps have been recaptured in fairly adequate numbers. The nine year data from 1975-76 to 1983-84 indicate that for every 3 fingerlings stocked, 1 kg has been recaptured (numbers of fish caught is not known) and this is a very encouraging picture. Increased rate of stocking and increased fishing effort will certainly raise the yield.

Gandhi Sagar (Madhya Pradesh):

In this large reservoir stocking has been minimal and it never reached one million which would have been a stocking rate of 15 fish/ha. Despite this low rate (maximum 12 fish/ha) the yield has been increasing, reaching a peak of 879 000 kg in 1979-80 (13.3 kg/ha).

Catla: This species was almost non-existent until 1963-64 and appeared in the catches in 1964-65 (2.3% - 36 958 kg). There was a steady increase and it eventually became the single predominant species, displacing all other carps. It constituted over 60% of the total catch from 1969 to 1980 (77.55% in 1972-73). Since this was attained with a low rate of stocking (1-4 fingerlings/ha), one must assume that the fishery has been sustained by continuous recruitment. Since catla is the choice species for marketing, even this modest yield is lucrative for the fishermen.

Mrigal: From a 55% of the total in 1963-64, this species has been decreasing inversely with the increase of catla catches. Since 1967-68 the catches became insignificant, representing less than 4% of the total. Stocking rate has been a low 1-3.5 fingerlings/ha. The yield from this stocking is uneconomical. There seems to be no natural recruitment.

Rohu: The performance of this species is worse than that of mrigal. Stocking rate is low and recruitment nil. Mostly the catch was less than 1% of the total.

L. calbasu: This major carp has been yielding good catches until 1971-72 (27.2%-12.6% of the total), but then the catch suddenly dropped to less than 4%. There seems to be a very inadequate stocking. With a massive stocking this species should regain its position, perhaps next to catla.

Tor sp.: This indigenous species does not contribute much to the fishery.

Common carp: Despite stocking, there was practically no recapture.

Gobindsagar (Himachal Pradesh): (See also the paper by Kumar, this volume).

Limited stocking was carried out since 1970-71 and the first commercial yield was 273 013 kg (1973-74). There has been a sporadic low stocking of major carps (9 to 50 fingerlings/ha).

Catla: Even with low stocking rate, there was a good harvest until 1978-79.

Nearly 210 t of catla were landed in 1977-78 (28.6%). Between 1979-80 and 1984-85, the catch was less than 10% of the total. This has been attributed to the competition from silver carp, which began appearing in the catches, starting in 1975-76. The initial stock of this species reached the reservoir through inadvertent escape of 300 fry from a pond. By 1979-80 silver carp contributed 6.8%, which was about equal to the catla catch of 6.4%. The decline of catla also coincided with the decline in total catches by almost 50%, from the high 842 220 kg in 1980-81 to 413 770 in 1983-84. Change in composition favouring catla might boost the total yield, but this would require an increase in stocking rate.

Rohu: The yield of this species declined from a high 191 630 kg (25.8% of the total yield) in 1978-79 to less than 5% from 1981-82 onwards. Inadequate stocking and negligible recruitment, compounded by interspecific competition from L. dero, has reduced the stocks of rohu. Since rohu was contributing a sizeable quantity of catch, intensive stocking could increase the catch of this species. It should be noted that minor carp, C. reba, has been increasing in the catches since 1981-82.

Mrigal: The position of this species is identical with that of rohu. A maximum of 16.5% of the total catch was reached in 1979-80,which was followed by a steady decline to less than 1%. Heavy stocking could improve the catches.

L. dero: This indigenous carp is of a low commercial value, but it represents a sizeable portion of the total catch, ranging between 37.5 (245 377 kg) and 23.0% (109 270 kg) in the 1980-81 and 1984-85 period.

Common carp: Gobindsagar is one of the very few reservoirs, where the species has been an outstanding success. The catches are high with a maximum of 264 430 kg (31.40%) in 1986-87. Stocking alone may not have caused this high output. There must have been a good deal of recruitment too. The thermal regime and other conditions seem to favour this species.

Silver carp: This Chinese carp, which was initially praised and welcomed, is now disfavoured by some fisheries scientists. It has been supporting a sizeable fishery without any stocking support. The peak catch of 354 277 kg (65.6% of the total) was attained in 1987. Since the reservoir is located at a geographical latitude of just above 31°N, the ecological features must be nearer to those of China.

L. calbasu: This species is not a common one and its fishery is insignificant.

In 1980-81, this reservoir gave a yield of 49.8 kg/ha. Since then, however, the total yield has been declining (see Kumar, this volume). With virtually no predators, the carp fishery could yield more if more intensively stocked and fished.

Rihand Reservoir (Uttar Pradesh):

This reservoir has been yielding high value major carps, especially catla, but the total catch has been low - 0.7 to 9.3 kg/ha/yr. The stocking rate was low - 0.19 to 20.5 fingerlings/ha/yr.

Catla: This species dominates the reservoir catch, accounting for 99.1% of the total yield in 1974-75. A similar catla-dominated reservoir in Tamil Nadu has given yields of over 150 kg/ha (Sathanur Dam). In the latter, fish stocking has helped to diversify the species mix, with most of the major carps well represented. In Rihand it is necessary to stock other major carps such as rohu, mrigal and L. calbasu to raise the yield.

Kabini Reservoir (Karnataka):

The reservoir has been stocked with major carps and common carp at a rate from 33 to 327 seed/ha/yr, an average 172/ha for 5 years (1980-81 to 1984-85). The results are not considered satisfactory. The maximum yield in 1981-82 was 25.0 kg/ha. Cyprinids accounted for 14%-20% of the total. The low yield is due to inadequate recapture of carps stocked. Catches of tilapia increased from 8% in 1980-81 to 60% of the total catch in 1983-84. With the increase in tilapia catch, the total yield decreased. This is an example where the tilapia could not increase the total yield through its predominance.

Krishnaraja Sagar (Karnataka):

The data for 1972-73 to 1978-79 show an annual catch from 150 to 300 t (average for 7 years - 200.5 t or 15.66 kg/ha). The reservoir was stocked with major carps and common carp. The stocking rate varied from 21 500 to 352 000 seed/yr for common carp and 100 000 to 352 000 seed/yr for the major carps (1.7-27.5 and 7.8-26.4 fingerlings/ha, respectively).

For all these years the catch composition is reported to be: common carp 35%, L. calbasu 30%, Gangetic carps 10%. In the total, carps accounted for 91% and Wallago attu for 7%. From 1970-71 to 1980-81 the expenditure on stocking was far in excess of revenue. In the absence of recruitment, stocking rate appears to be too low. A noteworthy feature is the disappearance of the important native carp Puntius dubius.

Tungabhadra Reservoir (Andhra Pradesh):

This large reservoir (37 814 ha) has been poorly stocked, the rate ranging from 1.3 to 11.2 fingerlings/ha/yr. Total yield is deceptively high - the highest being 4 200 t in 1981-82 (111 kg/ha/yr); 90% of it was "trash fish". This is also the situation now. This reservoir has one of the largest fish breeding and rearing centres attached to it. Until 1983, the fish seed farm had a waterspread of 4.7 ha and a production of 30 million fry and fingerlings a year. This material should have been utilized for stocking the reservoir; however, only part of the seed was used for that purpose. This has resulted in a meagre yield of major carps despite a high total yield.

For 18 years the reservoir has been incurring loss, the expenditure exceeding the income by 30% (Indian Institute of Management, 1985). High production has not helped to make the reservoir fisheries profitable. Better management strategy should involve the elimination of trash fish and massive stocking of major carps.

Dhora Reservoir (Uttar Pradesh):

The catch from this 1 280 ha reservoir initially (1964-65) consisted of over 50% by weight of carps. During 1971-72, of the fish stocked 92% were rohu and in 1972-73, the highest catch rate of 78.7 kg/ha was obtained and of this 33% were major carps (IIM, 1985). From 1971-72 to 1981-82 over 3 million carp were stocked (50% of it rohu), at an average of 277 500 fry/year (270 fry/ha). Major carps contributed only less than 5% by weight of total yield between 1974-75 and 1981-82. "Trash fish" or "weedfish" which are small sized uneconomical species like Rasbora sp., Danio sp., Nemacheilus sp., Rasbora, Ambassis, Puntius, kolus and other minor barbels (B. machecola, B. ticto etc.) and Gadusia chapra accounted for 72.8% and 23.6% of the total yield respectively in 1980-81 (IIM, 1985). The reasons for the failure of major carps are not known but could also include bad management. The stocking rate needs to be increased.

Girna Reservoir (Maharashtra):

This 5 483 ha reservoir in an arid zone has been regularly stocked with carps including common carp at a rate of 18 fry/ha (100 000/yr). Total yield of 40.6 kg/ha was reached in 1982-83. The contribution of common carp was 17.9% over a period of 6 years from 1980-81 to 1985-86. It is reported that the annual revenue from common carp alone was Rs.280 000 (Valsangkar, 1987). In these six years, minor carps of low economic value dominated.

Stocking with Indian major carps, e.g. catla, rohu, mrigal and calbasu, will increase the total yield as well as the yield of stocked species.

Vaigai Reservoir (Tamil Nadu):

In this reservoir, due to drastic water level fluctuation and turbidity of the water, there is no stable fish population. Changes in fish species composition are unpredictable. For example, O. mossambicus contributed in 1964-65, 99% of the total catch of 45 770 kg (Sreenivasan and Sunderaraj, 1967), but in 1967-68 decreased to 3.1%. In 1972-73 it again increased to 72.3% of the total catch. In 1979-80, it was down to 0.4% and since then it has not contributed to the fishery, remaining below 3%. This coincided with the increase in the predatory Wallago attu to 40.6%-75.0%.

Catla: Catla did contribute sizeable percentage to the catch from 1966-67 to 1970-71 (12.3%-45.8%).

Rohu also formed a sizeable percentage of the total catch from 1979-80 to 1983-84 (10.1% to 17.2%). Stocking was reflected in the catches.

Mrigal: In some years, e.g. 1970-71 to 1973-74, this species contributed 17.0% to 24.4% of the total catch. In the last 8 years despite heavy stocking the contribution from this species was low.

L. fimbriatus: This species was not successful in this reservoir.

Common carp failed to survive in this reservoir. Minor carps P. sarana and C. reba dominated the catches in many years.

Ramgarh Reservoir (Rajasthan):

This is a desert impoundment. Fisheries activities were started only in 1969. Indian major carps are among 29 species present and they are reported to be breeding in this water. The stocking rate ranged from 137 to 2 153/ha. The catch composition shows that major carps contribute 45.1 to 90.0% of the catch, the rest being shared by minor carps. Among the major carps catla ranged from 8.8% to 50.8%, rohu from 10.8% to 49.3%, mrigal from 5.3% to 25.6% and calbasu from 1.6% to 19.9% (IIM, 1983). Major carps have been well stocked and their yield ranged from 24.6 to 98.7 kg/ha. Because of the domination of carps, the revenue has been good and profitable. There are no tilapias and the density of the predator Wallago attu is low. This is an example of a good carp reservoir.

Jaisamand Reservoir (Rajasthan):

This is the oldest man-made lake in India, established in 1711 A.D. It covers an area of 7 296 ha. The catch ranged from 180 t/yr in 1973-74 to 959 t/yr in 1979-80 (i.e. 24.7 and 131.6 kg/ha). Major carps (catla, rohu, mrigal, calbasu) formed over 50% of the total catch in the earlier years (1962, 1963, 1964) but later on decreased to less than 34%. The average weight of catla was 8-10 kg, mrigal 3 kg, rohu 1.5 kg, calbasu 1.5 kg. The yield has been high but removal of trash fish and catfish would increase the yield.

2.2 Thailand

Among the Southeast Asian countries, Thailand has a rich fish fauna of its own. 250 species of cyprinids are important as food and Ubolratana Reservoir alone has about 68 species. Exotic introductions such as the Chinese carps Ctenopharyngodon idella, Aristichthys nobilis, Hypophthalmichthys molitrix, the Indian carp Labeo rohita, the common carp, and Oreochromis niloticus were made in some reservoirs (Baluyut, 1983). The reason for low yield from these reservoirs is the high proportion of predators (Pawaputanon, 1987). After impoundment the catches of cyprinids decreased from 55.9% to 24.1% in Ubolratana reservoir (Sidthimunka and Potaros, 1968), while the predators increased. The fish catches from important Thailand reservoirs have been well documented (Bhukaswan, 1976, 1980; Pawaputanon, 1987; Baluyut, 1983). Annual data on species-wise stocking and catches for the Ubolratana Reservoir are now available (Bhukaswan, this volume).

In Ubolratana Reservoir, 5.8 million fish seed were stocked between 1965 and 1981. Among these were the following important species: bighead carp 7 000, grass carp 4 397, *Puntius gonionotus* 3.14 million, silver carp 44 000, rohu 1.458 million, common carp 101 700, *Puntioplites proctozysron* 481 544, *Probarbus jullieni* 228 000, etc. (Baluyut, 1983, Table 61). It is stated that only 1% of stocked fish were caught. Some of the introduced species have shown good growth (Bhukaswan, 1976) but the stocked *Probarbus jullieni* are not recovered. *Puntius gonionotus* have been occurring in the catches regularly, which is considered the result of successful stocking. 239 000 kg have been caught against a stocking of 3.14 million. *C. molitorella* failed to appear in the catches. *Puntioplites proctozysron* are so abundant in the catches that self-reproduction is probably more important than stocking. *Osteochilus hasaelti* has also been contributing regularly to the catches without being stocked. Thus, cyprinids have formed the bulk of catches in Ubolratana Reservoir. Tilapias were noted only since 1980 (Baluyut, 1983).

In reservoir Lam Takong, *Oreochromis niloticus* was the dominant species (15.8% of the total catch), but the average yield of this reservoir was only 22.3 kg/ha in 1975 (Baluyut, 1983). The introduction of the exotic *Aristichthys nobilis* was successful in Chulaporn Reservoir, forming 7.2% of the total yield (only 5 000 seed were stocked in 1975 (Baluyut, 1983).

O. niloticus were also stocked in Kawlom and Lam Praplarong reservoirs in 1972 and 1973 but recapture from these has not been reported. The total catch from the latter was high - 138 kg/ha (Baluyut, 1983). A large quantity of rohu was stocked in Chulaporn Reservoir. Rohu, grass carp and silver carp are said to have established themselves in Ubolratana Reservoir. Pawaputanon (1987) has reported that 20% of tagged rohu stocked in Ubolratana were recovered. He attributes the low recapture of mrigal, rohu, Chinese carps, common carp, etc., to the small size at stocking, and to the presence of excessive predators. Bhukaswan and Pholprasith (1977) recorded the gradual increase in carps from 48.1% of total yield in 1969 to 72.0% in 1975 which is a desirable improvement on the earlier findings of Sidthimunka and Potaros (1968). Catfish and murrels together decreased in the same period from 31.1% to 3.4%. The total catch rose from 2 110 t to 2 448 t.

In the decennium 1978-1987, a total of 127 856 million Chinese, Gangetic and common carps were stocked in Thai reservoirs and lakes, in addition to 167 785 million indigenous cyprinids (an average of 126 fingerlings/ha/yr). The total catch of exotic carps caught during 1977-1986 was 26 827.34 t valued at 555.25 million bahts. The stocking cost averaged 2.96 million baht/yr. The high profitability is made possible by judicious stocking. Seed production in hatcheries consisted of *P. gonionotus*, *Labeo rohita*, *Cyprinus carpio*, and Chinese carps (in that order). From the data of Bhukaswan (this volume) it is seen that 3 103.76 t of rohu and 10 698 t of Chinese carps were produced in 10 years, fetching 68.97 and 153.11 million bahts, respectively, which was very profitable. The Chinese carps performed exceedingly well in Thailand. The high yields from Thai reservoirs are due to good management. Thailand is an example of succeas of stocking Asian carps in large water bodies.

2.3 The Philippines

The species poverty, with the presence of local species of no particular economic value, has been the cause of low inland fish production. Exotics such as chanos, tilapia, common carp, rohu, gourami, Puntius javanicus, Trichogaster pectoralis, and T. trichopterus were introduced to augment fish supplies. The common carp and Asiatic carps (which includes rohu as the major component) seem to have been successfully established (Baluyut, 1983).

In Laguna de Bay, from 1961 to 1965, 70 000 common carp, 4 000 tawes (P. javanicus) and 19 000 tilapia were stocked. 448 t of carps (rohu and common carp), 1 510 t of chanos and 548 t of tilapia were captured in 1979. Over years, capture fisheries seems to have declined, as illustrated by the data given below (Baluyut, 1983, 1987).

Year	1963	1968	1973	1976	1984
Capture fisheries (t)	82 882 (921)	39 055 (433)	20 723 (246)	27 359	92 856
Pen fisheries	-	-	19 294	47 020	81 966

(Figures in parentheses, kg/ha)

By 1980, the production of common carp and Asiatic carps (rohu, etc.), rose to 16 493 t out of a total of 54 535 t (i.e. 30.2%) while tilapia contributed only 3 642 t (6.68%).

Rohu is reported to have grown to 24 kg in three years and also breeding naturally in the Pampanga River, and it has also been spawned by hypophysation (Datingaling, 1977).

In the lakes, carps seem to be dominant. In Lake Lanao in 1963-64 (Villaluz, 1966) common carp (Bangkok variety) yielded 237 250 kg (11.9%). The other cyprinids yielded 981 120 kg, while tilapia yielded 109 500 kg(5.5% of the total catch of 1 986 330 kg). In Lake Buluan, however, tilapia gave higher yields (30.8%), but carps still dominated with 52.8% of the total of 10 000 t in 1980 (Baluyut, 1983).

In reservoirs, stocking rates have been very low, although the species mix has been very much balanced and with desirable species, i.e. common carp, rohu, Chinese silver carp, bighead carp, O. niloticus. In Pantabangan Reservoir, the rate varied from 5.3 fingerling/ha/yr to 58.9/ha/yr with an average of 17.3/ha/yr (for 4 years). In Angat Reservoir, the total stocking was only 29 500 fingerlings (for 3 years). In Caliraya Reservoir, the stocking was 46 560 or 10 fingerlings/ha (for 4 years). Yield data are not available. However, out of the total "Inland Municipal finfish catches", common carp contributed a sizeable quantity in the individual years as follows: 1976 - 4 090 t (5.5%), 1977 - 4 873 t (5.9%), 1978 - 20 579 t (30.0%), 1979 - 9 709 t (23.4%), and 1988 - 16 493 t (30.2%). During the same period tilapia formed 6.7% to 27.4% of the total. A high yield of 6 726 t was obtained from Magat Reservoir (4 460 ha) mainly through tilapia, catfish and goby. Angat, which had 75% tilapia, yielded only 87 t (Guerrero, 1988). In

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Lake Lanao, tilapia catches were 13.6, 7.0, 24.2 and 37.6% of the total, for the years 1984, 1985, 1986 and 1987 respectively, while in 1963-64, cyprinids accounted for 49.39% of the total (Baluyut 1983). In Lake Buluan carps gave high yields of 26.0, 372. 17.1 and 39.0% respectively during 1984, 1985, 1986 and 1987 (Baluyut 1987). In Lake Mainit in 1984, 37% of catches were tilapia.

2.4 Pakistan

In the newly formed reservoirs, catla, rohu, mrigsl snd common carp were introduced and these together with the mahseer (*Tor putitora*) are reported to have given good results (Naik, 1987). Qusntitative data are not available. In Tarbela Reservoir common carp and mrigal are reported to be well established and achieving good growth. Introduction of *T. pectoralis* and gourami failed. Grass carp was introduced in 1984, but there is no information on its performance. *O. mossambicus* was introduced in 1951, but there are no data on its establishment. In a country possessing fast growing, large-sized carps, cichlids may not be viewed favourably.

In Chashma Reservoir (17 287 ha) the yield has been about 40 kg/ha, and in Mangla Reservoir (26 500 ha) it is 65 kg/ha. It is believed that regular stocking of reservoirs with Gangetic and major carps, silver carp and common carp would increase their yield.

2.5 Bangladesh

This country is rich in carp resources since it shares with India the Gangetic system with the Indian major carps catla, rohu, mrigal and *L. calbasu*. However, quantitstive data on exotic introductions including tilapias and Chinese carps are not available. With the indigenous and exotic fish seed availability the yield could be substantially increased. Kaptai Reservoir produced 4 057 t/yr (69.6 kg/ha) in 1984. Since 1985 the total catch declined along with a decrease in major carps from 57% in 1976 to a low 18% in 1985 (Rahman, 1988). High yield of carps (900 kg/ha) is reported for 1984-85 from the Buluhar floodplain as a result of stocking (Choudhury, 1987).

2.6 Nepal

Seed production serves both aquaculture and capture fisheries with Chinese carps in the forefront. These and the common carp are reported to give "adequate survival and improved yield". From 21.68 kg/ha/yr the catch of fish in Begnas Lake increased to 25.9 kg/ha/yr by stocking Chinese and common carps (Rajbanshi, 1987).

2.7 Malaysia

Since 1970, for 9 years 12.98 million fish seed were stocked (36 fingerlings/yr/ha) (Baluyut, 1983). The species introduced are *Puntius gonionotus*, *Cyprinus carpio*, *Trichogaster pectoralis*, *Osphronemus gouramy*, *Helostoma temmincki*, *Aristichthys nobilis*, *Hypophthalmichthys molitrix*, *Ctenopharyngodon idella*, *Cirrhina molitorella*, *Puntius orphoides*, *Oxyeleotris marmoratus* and tilapias. The catch composition in 1980 for inland fisheries was *A. nobilis* 16.8%, *C. idella* 18.1%, *P. gonionotus* 8.2%, *C. carpio* 3.8%, *T. pectoralis* 4%, *Channa* sp. 8.1%, *Clarias batrachus* 11.2% and *Oreochromis mossambicus* 6.5% (total catch 1 018 397 kg). Except silver carp, the Chinese carps have done well. Khoo (1987) has stated that annually one million fry are stocked in each reservoir, but the impact is minimal. Cyprinids account for about 60% and tilapias for 6.5% of the yield. Inland capture fishery needs to be developed.

2.8 Indonesia

There are over 800 species of fish in Indonesia and 17 exotics have been introduced. The present level of inland fish production is 19.6 kg/ha/yr, as against a potential of 57 kg/ha (Sarnita 1987). According to Hardjamulia and Rabegnatar (this volume) fish stocking has been limited and it is as yet not possible to evaluate quantitatively the extent of contribution of fish stocking in increasing the fish catch. The major species introduced are *O. mossambicus*, *O. niloticus*, *C. carpio*, *T. pectoralis*, *P. gonionotus* and *Clarias batrachus* and these are reported to have achieved good results (Sarnita 1987). Common carp, *P. gonionotus* and *Osteochilus hasselti* have been used in reservoir fisheries management. Two tilapias (*O. niloticus* and *mossambicus*) are also reported to have been stocked (Hardjamulia, *pers.comm.*). *H. molitrix*, *A. nobilis* and *C. molitorella* also introduced into Indonesia, have not established themselves (Sarnita 1987). The highest catch of common carp in a reservoir was 10.4% of total yield in Saguling. But in the lakes Anggi and Paniai, common carp monopolized the catch with 100% and 84% respectively (Hardjamulia, this volume). In Paniai Lake, the stocking efficiency is very poor with stocking of 500 000 fry resulting in the yield of 3 612 kg only. In Lahor reservoir in East Java, after stocking 78 000 common carp in 1977-80, only 5.6% of the catch came from this species in 1979-85 (Sarnita, 1987a). In Lake Toba, the common carp formed 1.6% to 13.0% of total catch during 1980-84.

In reservoirs, the cyprinids, *P. gonionotus* and *Hampala macrolepidota*, dominated the catches in Jatiluhur with the two species yielding 46.9% and 30.3% of total catch respectively. In Saguling reservoir, *O. hasselti* yielded 25.7% and *Hampala* 30.5% of total catch; in Wonogiri reservoir, *P. gonionotus* and *Hampala* formed 24.3% and 16.9% of the total catch. Cyprinids in all accounted for 80.7, 84.2 and 58.0% of the total yield from Jatiluhur, Saguling and Wonogiri reservoirs respectively (Hardjamulia and Rabegnatar, this volume). However it was in Lake Tempe where the introduction of *P. gonionotus* was a great success, accounting for 70% of the total yield. According to Petr (1984), *C. carpio* and *P. javanicus* have established themselves in Selorejo reservoir successfully, yielding a catch of 110 kg/ha. In Karangkates reservoir, 200 kg of common carp fry, 100 000 of *P. javanicus* and "thousands" of Nile tilapia were stocked in 1973 and after 12 years, i.e. in 1985, their contribution to this reservoir production was 12%, 26% and 5% respectively (Hardjamulia, *pers.comm.*, 1988). In Lahor reservoir, 96 000 fingerlings of *P. gonionotus* were planted in 1978 and 1980 and 12% of total catch were from this species during 1979-85. From 1965 to 1981 in Jatiluhur reservoir, 7 970 kg of fry numbering 735 600 were stocked (none from 1982 to 1986), comprising *P. javanicus*, *O. mossambicus*, *H. temmincki*, *O. goramy*, *C. carpio*, *T. pectoralis*, *O. hasselti* and *O. niloticus*. Despite stocking of 142 300 *O. niloticus* (3 520 kg by total weight, of average weight 25 g each), the yield from this reservoir was only 3.6% of total catch in 1987 (Hardjamulia, *pers.comm.*).

O. mossambicus was the dominant species in the catches of Karangkates (86.0%) and Selorejo (90%) reservoirs and in Toba (96%) and Bening (79.2%) lakes. In Lahor reservoir it formed 50% of total yield. In Lake Toba, tilapia continuously contributed to high yields: 96.0%, 85.6%, 87.9%, 62.0% and 95.8% respectively in the years 1980-84. The total yield during these five years was 2 464, 1 080, 270, 645, and 827 t respectively (Sarnita 1987a).

2.9 Sri Lanka

Fish introductions into Sri Lanka have been tabulated by De Silva (1983) and Chandrasoma (1983). Oreochromis mossambicus, introduced in 1951, has been acclaimed as "a rare example of this species being a beneficial introduction" (Pullin, 1985). Fernando (1973, 1977) has recorded the spectacular increase in the inland fish catch of Sri Lanka, mainly due to tilapia. He also asserted that "if a choice has to be made between Indian carps and African cichlids, African cichlids would serve a more satisfactory alternative". He has also stated in the same paper that "one could consider the large Indian carps or tilapias for introduction into Ceylon".

Inland fishery yield which was 300 t in 1955 reached 36 000 t in 1986, mainly through a single species, O. mossambicus. However, this has its drawbacks, one of which is the stunting of the stock as reported by De Silva and Fernando (1980). Stocking of Indian major carps in a systematic way in Sri Lanka waters commenced from 1983 when catla, rohu and mrigal were successfully spawned by hypophysation technique in the breeding stations. Where adequately stocked, the results have been spectacular.

Stocking of Chinese carps commenced in 1978 (Jayasekara, this volume). In Kandalama reservoir, 305 000 fingerlings of rohu were planted between 1983 and 1985 and a total of 34 428 kg rohu were captured during 1984 and 1985, while during the same period, 458 250 rohu were stocked in Udawalawe reservoir and 54 159 kg of these were recaptured. 28.23% of total catch of Kandalama reservoir was rohu. In 1987, the yield of rohu rose to 47% of total yield. In Bowatenne reservoir, rohu formed 47% of total catch in 1985, and 38.5% in 1987. In an upland reservoir Moussakelle, rohu contributed 16.63% by weight to the catches in 1986 (Jayasekara, this volume).

Catla has started appearing in the catches in Pimburettewa reservoir, accounting for 2.3% of the total catch in 1987, from the stocking of 2000 fingerings in 1985. In Polonnaruwa district 17.5% of stocked catla are reported to have been recovered. Mrigal gave a 8.5% and rohu 5.1% recovery (all in numbers) (Jayasekara, this volume). In Kandalama reservoir 3.8% of total catch by weight was mrigal, in 1987.

Silver carp yielded 7.3% by weight of total catch in Ulhitiya reservoir, though in other reservoirs where they have been stocked, viz., Polgolla, Castlereigh, Giritale, Kaudulla, Pimburettewa, Parakrama Samudra, Tabbowa, etc. there is no evidence of recapture nor was any recaptured in Polonnaruwa district (Jayasekara, unpubl.). The bighead carp yielded 7.8% by weight of total catch in Kandalama reservoir in 1986, but none so far (1987) in Parakrama Samudra, Tabbowa, Siyambalakotuwa, Pimburettewa, Maduru Oya and Castlereigh reservoirs. But in Giritale reservoir, the bighead accounted for 15.2% by weight of total catch (1985-86), and a very negligible quantity in Minneriya reservoir (Jayasekara, this volume).

The performance of common carp was satisfactory only in some upland waters: 16.5% in Polgolla and 12.26% in Mousakelle. It was a failure in Minneriya, Kaudulla, Maduru Oya, Pimburettewa, Parakrama Samudra, Balaluwewa and other reservoirs. Very low recapture of less than 2% of total catch was recorded from Polonnaruwa district and in Pimburettewa - 0.25% (in 1987). In Matale district the reservoirs yielded 17.0% to 24.9% of Labeo dussumieri in 1983.

The indigenous carp, Labeo dussumieri dominated the catches in Siyambalakotuwa (94.23% of total yield) and Kaudulla (75.6% of catch up to 1985). In Nalanda reservoir, it contributed 22.29% by weight in 1983-84. In Giritale, Minneriya, Pimburettewa, Parakrama Samudra and Kandalama reservoirs this species contributed to over 5% of total catch without stocking (Jayasekara, this volume). The other native carp, Puntius sarana, was present in noticeable quantities in Giritale, Polgolla, Bowatenne, Minneriya and Pimburettewa reservoirs, without being stocked.

The following information on the Indian major carps in other reservoirs of Sri Lanka is collated from available literature and unpublished records. In Senanayake Samudra 50 100 rohu were first stocked in September-December 1983. It was reported that from February 1984, daily 5 to 6 rohu started appearing in the catches and that by September 1984, one year old rohu of average weight 3 kg each were being caught. In Unnichai Reservoir 20 000 rohu were stocked in the last quarter of 1983 and recapture started in February 1984. By August 1984 the weight of rohu was 6.4 kg each and daily 4-5 fish were being caught (Poobalapillai, pers.comm.). In Padaviya Reservoir 13 000 rohu were stocked in July, and in May the following year, fish weighing 2.5 kg each were caught. In Tabbowa Reservoir 20 000 rohu were stocked, and the next year a yield of 649 kg was recorded. The other reservoirs in which rohu were stocked during 1983-84 are: Ulhitiya 34 500, Rathkinda 30 000, Maha Uswewa 20 000, Meepana Arawewa 3 000, Aliyagala wewa 3 000, Muruthawela 11 500, Nagadeepa 1 000, Galkulama 250, Wahalkada 6 000, Dambullaoya 43 950, Maduru Oya 17 750, Giritale 2 000, Kalawewa 7 500, Ingenimitiya 126 650, Sorabora wewa 1 750, Dambarawa 7 300, etc. The results of stocking are to be monitored. De Silva (this volume) calculated the "stocking efficiency" for rohu in Kandalama and found it to be very high. In Giritale and Tabbowa reservoirs it was also high (calculated according to Li, 1988).

The bighead was a success in Giritale (15.2% of the total yield) where a very high stocking efficiency was achieved. The same was in Kandalama. In Pimburettewa, the stocking efficiency for catla was also very high. The results portend well for carp fisheries in Sri Lanka reservoirs. Rohu has also done well in seasonal tanks.

The Chinese bighead carp has given very satisfactory growth and recapture in seasonal tanks of Sri Lanka (Thayaparan, 1982). In some reservoirs the species has also started to appear (Maduru Oya, 3 382 kg in January-February 1984). In Giritale Reservoir, the bighead carp yielded 3 433 kg (13.7%) out of 24 994 kg (10 months of 1984).

The common carp does not seem to be successful in Sri Lanka reservoirs. But it has shown good growth (with low survival) in seasonal tanks. There is insufficient information about the other Chinese carps.

2.10 China

The People's Republic of China has made giant strides in inland fisheries and achieved a catch of 380-450 kg/ha from open waters. The fishes stocked in reservoirs are: silver carp, bighead carp, black carp, grass carp, common carp, crucian carp, bream and some others, of sizes 15-20 cm/50 g (Pillay, 1979). In Tanghu Lake, 95.5% of fish caught are stocked ones. Very high rate of stocking characterises the Chinese management strategy, for example, Mei-chun, a 2 500 ha reservoir where the stocking rate is 4 800 fry/ha (12 million fry). The yield, however, was only 40 kg/ha and the survival of stocked fish was 5-7%. In some reservoirs high yield was recorded, as follows (from Pillay, 1979):

Reservoir	Area (ha)	Average depth (m)	Stocking (millions)	Production (t)	Production kg/ha
Taihu	225 000	2	3	12 000	53
Tingshan	7 000	4	10	1 000	143
Tonghu	1 467	4	4 (fingerlings)	660	450
Paitan	400	2	30 (fry) 1 (fingerlings)	300	750

A strategy worth noting is that the water from big reservoirs is directed to smaller reservoirs to ensure storage for fish culture. The yield from large reservoirs (10 000 ha) was 60 kg/ha while that from medium and small reservoirs was 225 kg/ha and 500-1 000 kg/ha respectively (Tapiador *et al*., 1977). Seed farms near the reservoirs supply the fry and fingerlings, which are disinfected before stocking. Time and place for stocking are carefully chosen (Song, 1980). In China, mrigal has been successful and has grown much better than the native silver carp and bighead carp in the first five years (Song, 1980) - 8.0 kg for mrigal as against 7.5 kg for bighead carp and 4.2 kg for silver carp. Not only are the native Chinese carps stocked in reservoirs, but also five species of tilapia, rohu, mrigal and crucian carp. Multi-species stocking is the rule. Data on species composition of catches are not available. With continuous stocking, in Chang Shouhu Reservoir 84.6% yield was from stocked fish, while in Qing Shan Reservoir, it was 97% (Lu, 1986). This reservoir gave yields of 548 kg/ha/yr over 22 years. The principle of "stock and take" gave a stocking efficiency of 14.4 (Li, 1988). The introduction of crucian carp from Japan (*Carassius auratus*) was very successful (Tong, this volume). *O. mossambicus* "was not attractive due to its slow growth, small size and low preference by consumers". The highest yields in Chinese reservoirs were from the ones dominated by bighead and silver carp (Li, 1988).

The successful artificial propagation of Chinese carps since 1958 by hypophysation has led to a "boom" in the development of reservoir fisheries. 1.3 billion fingerlings were stocked in 1984 and the fish yield from reservoirs in 1985 was 200 000 t (Li, 1986). Stocking fingerlings of size 16.5 cm leads to 50% recapture. Stocking of crucian carp in Wuyi reservoir yielded 112-150 kg/ha for the past one decade while the southern reservoirs stocked with another carp, Cirrhinus molitorella, yielded 225 kg/ha. In the 800 ha Quing Shan reservoir none of the original species could support a commercial fishery. The major species stocked were the bighead and silver carp, to a lesser extent grass carp, black carp, and the bream were stocked and yielded only 4.4% of total catch while the bighead and silver carp together yielded 95.6% by weight of total catch in 22 years. In this period, 24 537 million fingerlings were stocked - bighead 41.6% and silver carp 32.2% (Li, 1986). The "return rate" was 49 and 51% respectively. One kg of stocked fish yielded 14.4 kg marketable fish. The average yield from this reservoir was 660 kg/ha (1969-79) and 682.5 kg (1980-83).

3. DISCUSSION

3.1 Indian situation

In most of the larger reservoirs of the Indo-Pacific region interests other than fisheries indicate the water management priorities, often leading to a situation in which the water regime is not ideally suited for obtaining high fish yields. The changes that take place are often unfavourable for native species. The altered flow pattern may affect self-sustaining populations. The usual management decision then is to enhance stocks by regular stocking of such species which thrive in the new lacustrine environment. If necessary the "threatened" native species are restored, for example, by the hormone breeding and stocking, as is the case with the mahseer (Tor spp.) in Maharashtra and Karnataka States.

As far as growth rate is concerned, the Indian major carps - catla, rohu, and mrigal in that order - are fast-growing and grow to a larger size than other Asian carps. The Chinese carps, especially the grass carp, the silver carp and the bighead carp, grow equally well in tropical environment and at times even better than the Indian major carps (Prabhavathy and Sreenivasan, 1977). Fish growth is site-specific and so variations have to be expected.

It has been mistakenly stated that the Asian carps (especially Indian carps) are neither tropical nor lacustrine and so cannot be expected to do well in tropical reservoirs (Fernando and De Silva, 1984). They consider tilapia as a truly lacustrine species, but O. mossambicus has come from the coastal streams of eastern Africa (Moyle, 1976 cited by Senanayake and Fernando, 1980). High yields in O. mossambicus dominated water have been cited (Fernando, 1977, 1980). However, "for every glowing success story, there is at least one story of stark failure in that the introduced exotic has had a markedly deleterious impact on some valued fishery" (FAO, 1980). There is a recent example of Bhavanisagar Reservoir (South India) in which in the last 4 years, i.e. 1984-85 to 1987-88, the percentage of tilapia in the total yield increased and remained around 15%, in parallel with a reduction in the total yield (Sreenivasan, 1988). Most drastically affected was the fishery of L. calbasu and the native P. dubius. During these last four years the total yield has been 7.2 - 22.4 kg/ha, while in the "pre-tilapia" period it reached a maximum of 43.5 kg/ha. Trans-basin transplantation of L. calbasu met with great success in Bhavanisagar. With a very low rate or no stocking, this carp sustained a good fishery for over two decades since 1963-64. To a lesser extent this species also succeeded in Stanley Reservoir (Mettur Dam) where 2.3 million of stocked fingerlings yielded one of L. calbasu. In Sathanur Dam too, L. calbasu provided good recapture when stocked. In Gandhisagar (Madhya Pradesh) a good fishery of L. calbasu existed initially, but due to inadequate stocking later on, its contribution was reduced to less than 4%. Ramgarh Reservoir shows the success of this species if stocked. In Pong Dam (Himachal Pradesh) during 1980-81, L. calbasu yielded 24% of the total catch and it is believed that a stable fishery could be based on this species. In Nagarjunasagar where L. calbasu was a native, the fishery declined with the increase in predatory catfishes. Heavy stocking of this species in Vaigai Reservoir in Tamil Nadu failed to yield any returns because of predatory fish. This is a suitable and desirable species to be stocked in reservoirs in the South Asia Regional Co-operation countries and L. fimbriatus and L. kontius have totally failed in their native waters after they were impounded.

Common carp seems to be unsuitable for deep reservoirs with very rare exceptions. Even in reservoirs with very negligible predator populations, e.g. Amaravathy, Sathanur, they did not succeed. Only in the shallow Uppar Reservoir of Tamil Nadu, there was adequate response to stocking. Gobindsagar is a classic exception where a large, deep reservoir sustained a good fishery of common carp (31.4% of the yield in 1986-87). In Girna Reservoir (Maharashtra) common carp is reported to give a good yield (17.93% average for 6 years) and revenue (Valsanagkar, 1987). Common carp seems to have been successfully sustained in the Philippines. In Indonesia only one reservoir (Selorejo) is cited as having a fishery of common carp (Petr, 1984). In Sri Lanka, this has not been much of a success in tilapia-dominated environment, but in the uplands (Mouskeliya Reservoir) it was fairly abundant (25% of the yield).

Catla, the largest carp, is ideal for most of the reservoirs, especially for the large ones. Yields can reach 189 kg/ha as in Sathanur Dam. In Stanley Reservoir, the high price fetched by the fish makes it a very desirable species. Hence stocking should supplement and when necessary supplant the failure of natural recruitment. In northern India, Gobindsagar has been giving high yields of catla until recently, and suggestions have been made to revive the declining fishery. In spite of catla contributing over 90% of the yield and a high revenue in Rihand Reservoir, the production is low and it could be raised by diversified stocking at higher rates than those at present. In Gandhisagar catla catch reached over 70% of the total which was more than to be expected from stocked fingerlings. More intensive stocking with L. calbasu and mrigal is suggested for this reservoir to provide this species to fill up all niches. The present catch of 13.3 kg/ha is low, although still profitable. Catla is worth introducing in all IPFC countries, for its excellent growth and consumer preference.

Rohu has not performed very consistently in reservoirs. Since 1972-73 there has been an appreciable rohu fishery in Stanley Reservoir (31.1% in 1984-85) which could be attributed to good stocking. Heavy stocking since 1982-83 is clearly reflected in the catches of rohu. It has been giving good harvest in Vallabhsagar (Gujarat), but rohu has declined from 51.9% to 8.8% in 9 years due to very poor stocking, i.e. at a rate from nil to 25.2 fingerlings/ha. The ratio of stocked fish to the fish catch is low, which is good, but the total yield can be raised by high density stocking and better exploitation. It is reported that hilsa (shad) is appearing in the catches, and if established this clupeid may provide a profitable fishery.

The decline in rohu fishery in Gobindsagar is attributed to the increase of silver carp. It appears to be due to L. dero (Gauses' principle, which is the inability of two species to maintain themselves in the same niche, i.e. competitive exclusion). Stocking will restore the pre-eminence of rohu. In Sathanur reservoir stocking of rohu has also been successful and rohu appeared in catches since 1977-88. Even in the predator-dominated Vaigai reservoir, where Wallago attu is abundant, after the disappearance of tilapia, the landings of rohu increased. However, in some reservoirs (e.g. Gobindsagar, Bhavanisagar) rohu has not contributed to the catches.

Mrigal stocking has contributed a good percentage to the yield from Bhavanisagar, Sathanur Dam and Gandhisagar. In the Damodar Valley reservoirs - Panchet, Maithon and Konar - mrigal provided a fairly substantial fishery (Jhingran and Khan, 1979; Jhingran and Natarajan, 1978), although the total yield was poor.

In general, it is possible to enhance the stock of fish in a reservoir by proper stocking. This is exemplified in the case of Aliyar Reservoir (Tamil Nadu). Since 1982-83 proper stocking with fingerlings of sizes above 10 cm resulted in a qualitative improvement in the fishery. During 1983-84, catla, rohu and mrigal contributed 68% to the fishery, and common carp contributed 21.1%. The yield was reported to have improved, being 70.0 kg/ha in 1986 (with 98.8% major carps) and 85.1 kg/ha in 1985 (with 66.6% major carps). Silver carp has started appearing in the catches.

From the Indian reservoirs discussed in this paper, Amaravathy is the only tilapia reservoir, while the rest are carp or catfish reservoirs. Amaravathy has a high primary production, the highest among the reservoirs (Sreenivasan, 1964). This production has been utilised by tilapia which gave high yields until the collapse of the fishery after 1984-85. The following increase in the population of major carps showed that the primary production could be utilised by carps. In Kabini Reservoir, Karnataka, the increase in percentage of tilapia did not ipso facto increase the total catch, but in fact it reduced the total yield. In Vaigai, another South India reservoir, predominance of tilapia did not lead to high total yields, the maximum being about 19.6 kg, and tilapia accounted for 99% of the total. Catch of the same magnitude was obtained even when the top predator Wallago dominated the catch.

Tungabhadra Reservoir in Karnataka is an example of a reservoir giving high yields but poor revenue. The total yield reached 4 200 t (111 kg/ha/yr at full water supply level), but 90% of it were minor cyprinids and there was a continuous loss of revenue from this reservoir. This is because of the bad management, i.e. very low stocking rate and failure to control and reduce the small cyprinid (trash fish) population. The problem is similar in Dhora Reservoir in Uttar Pradesh. A well managed carp-dominated reservoir was Ramgarh (Rajasthan). High yields reaching 98.7 kg/ha/yr were achieved with major carp as a result of good stocking.

The success of stocking in a few reservoirs is evaluated using Li's (1988) method. For Stanley Reservoir (1973-74 to 1987-88) the stocking efficiency (SE) is as follows:

Rohu: 9.5; L. calbasu: 47.8, and mrigal: 4.6.

For Bhavanisagar (1954-55 to 1979-80) the SE for catla is 46.8. This decreased to 16.6 during the next 8 years (1980-81 to 1987-88). It was 2.0 for rohu-mrigal. In Uppar (1984-85 to 1987-88) the SE was as follows:

Catla 21; silver carp 54.2; rohu, mrigal and common carp < 2.0.

Species mix has a bearing on the revenues from reservoirs. The Indian major carps fetch high prices in southern Indian reservoirs (with Calcutta as destination) followed by catfishes consumed locally. In the north, some catfishes are classified as 'A' class fish along with major carps for marketing. In terms of earnings it can be seen from the revenues of a few producers that profitability is lowest in tilapia reservoirs, better in catfish - carp mixed reservoirs, and best in carp dominated reservoirs. Case studies of Nagarjunasagar, Gandhisagar, Rihand, and others indicate the need for more intensive, judicious stocking and higher level of exploitation.

3.2 Reservoir fisheries in other Asian countries

The Philippines

Very high yields could be obtained even without the precocious breeding of tilapias, as exemplified in the shallow lake (90 000 ha) Laguna de Bay. Stocking of Indian and common carps even in low densities has given good recoveries with the common carp and rohu doing well. In man-made lakes, the rate of stocking has been very poor and needs strengthening to reach about 250 fingerlings/ha/yr. The present production of 100 kg/ha from reservoirs is proposed to be raised to 500 kg/ha (Datingling, 1977) which is possible. However, open water capture is giving way to pen culture and cage culture. Laguna de Bay alone gives a yield of 50 000 t/yr. As indicated earlier tilapia gave a higher yield than common carp. There is little information available on reservoir fisheries. Evaluating the success or failure of fish introductions thus becomes a very difficult task (Baluyut 1983).

Indonesia

Of the few cyprinids stocked in reservoirs, Puntius javanicus (= gonionotus) has given very encouraging results and is reported to breed in inland waters. Hampala macrolepidata is another successful species. Together with Osteochilus hasselti, the three cyprinids have been the mainstay of the fishery of three reservoirs, Jatiluhur, Saguling and Wonogiri. In the large natural lake Tempe P. gonionotus contributed 70% to the total catch, with the yield rate of 1 000 kg/ha, indicating that cyprinids can give similar high yields like tilapias. O. niloticus failed to dominate even when stocked in Jatiluhur Reservoir. Fish seed production in Indonesia reached 5.3 billion fry in 1972, as against a requirement of 5.7 billion. But for regular stocking of reservoirs still more seed is needed.

Thailand

Exotic Chinese and Indian carps have been introduced in Thailand. The Chinese bighead carp and rohu established themselves in some reservoirs. Carp fishery in some reservoirs has been profitable. Tilapia has not made itself a pest and has not contributed significantly to the total yield. Reduction of predatory fishes by selective intensive fishing and stocking of the fast-growing carps will raise the production from the inland waters of Thailand.

Sri Lanka

In 1942 only catla was introduced into Sri Lanka. Adequate trials were not made, but strong views were expressed that all Indian carps failed in Sri Lanka. De Silva stated that "repeated introductions of exotic carps into major reservoirs have not made any impact on their fisheries ... the number of exotic carps introduced (common and Chinese) over the years exceeded well over 3 x 10^6" Only in 1981, rohu and mrigal were brought to Sri Lanka as fry, reared to maturity and very successfully spawned in 1983. Likewise, catla fry brought in 1982, were spawned in 1984 and in the succeeding years all the three species were being spawned in Sri Lanka. First stocking of rohu was done in many reservoirs of Sri Lanka in 1983 and the results could be deemed to be spectacular. The price fetched by the Indian carps was more than that fetched by a large-sized tilapia. With proper stocking from the fingerlings obtained by hormone breeding (Balasuriya *et al.*, 1983; Kumarsini and Seneviratne, 1983) the Indian carps are sure to provide a good fishery of large-sized fish.

De Silva (this volume) has affirmed that the "stocking efficiency" of rohu is excellent in Kandalama and Udawalawe reservoirs. While dealing with smaller cyprinids he cautions that "it will not be advisable to commence a full-scale fishery all at once". Jayasekara (this volume) however feels that "minor cyprinids would not be preferred for direct human consumption". He has recorded a recovery rate of 17.5% for *Catla*.

In smaller water bodies (seasonal tanks) of Sri Lanka, carps seem to have fared exceedingly well. Recoveries (by numbers) are - bighead carp 47.7%, rohu 49.53%, catla 41.88%, common carp 33.63%, mrigal 45.29% and grass carp 22.16%. In terms of yield by weight their contribution as percent of total was 38.92, 22.67, 14.96, 11.81 and 2.67 respectively for bighead carp (and catla), rohu, common carp, mrigal and grass carp (Chandrasoma and Kumarasiri 1986). Harvests upto 72.9% of total yield from bighead carp and catla from these tanks have been recorded (Chandrasoma 1986). It would therefore seem reasonable to give priority for stocking smaller water bodies and intensively stock selected larger water bodies with exotic carps, which give higher returna to the producer. *O. niloticus* is coming into prominence in the catches in many reservoirs: highest yield being 72.17% in 1986 in Soraborawewa. The other reservoirs and the yield of *O. niloticus* are - Pimburettewa 49.1%, Rathkinda 39.7%, Dambarawa 37.1%, Ulhitiya 29.0%, Maduru Oya 22.8%, Nagadeepa 28.1%, Kalawewa and Giritale 15.6% and Parakrama Samudra 56.9%. It was worth noting that with the increase of *O. mossambicus* and *S. niloticus* from 58.0% in 1983 to 93.4% in 1986, the native carp *L. dussumieri* decreased from 40.0% to 6.57% in Nagadeepa (jayasekara, this volume). *T. rendalli* also seems to be establishing itself in some reservoirs contributing to 10-36.3% of catches (Chandrasoma 1986). The trend wherein *O. mossambicus* is being replaced by *S. niloticus* and *T. rendalli* is to be welcomed.

De Silva (1987) has noted that since 1983 "a more carefully planned stocking programme had been carried out in three major reservoirs". The bighead and common carp have made no impact on the fishery of any of them while L. rohita has resulted in a return of 20% which is encouraging. He rightly points out that the reason for failure was that the number stocked in a reservoir at any one time was too low and the stocking size was below the optimum. Further he states that the indigenous minor carps like L. dussumieri and B. sarana of Sri Lanka are unlikely to breed successfully in reservoirs. A judicious policy of stocking suitable species to raise the yield to provide higher income to the producer and consumer acceptability is desirable.

Even by 1983, the seed production in Sri Lanka exceeded 15 million. Rohu, mrigal and bighead carp were produced in millions. Though there may or may not be natural recruitment of these carps, the strategy of "stock and take" will still give good yields. Chandrasoma (1983) would like to stock select reservoirs with Indian carps. In Sri Lankan reservoirs, ranching as a capture fishery after proper stocking with multispecies carp combination will lead to high yields and profits. The Indian and Chinese carps which Fernando (1977) considers non-lacustrine species have been consistently used in "composite fish culture" in ponds which are lentic in nature. There is a reason why they would not succeed in semi-lotic conditions of reservoirs in Sri Lanka. The Inland Fisheries Development Technical Committee (1980) had recommended that "breeding of tilapia should be given up and the breeding of carps should be encouraged".

A fairly high productivity in Sri Lankan reservoirs through O. mossambicus has been a striking feature of the inland fisheries in the last two decades. But, as noted by De Silva (1984), the average size has gone down from 659 g to 191 g, and also the price of larger tilapia is twice that of smaller ones. The older reservoirs of Sri Lanka are shallow and bear no comparison with the deep and larger reservoirs of India, Thailand, Indonesia, etc.

Neal and Smith (1982) mention the relative economics of rearing and marketing as one of the forces influencing fisheries development. De Silva (1984) feels that continuous stocking of carps would not be economical. However, one example of stocking of rohu in Sri Lanka would suffice to prove its profitability. Financial rate of return of 269% and 281% respectively was obtained by Ilukkumbura (1986) for yields of rohu in Kandalama and Udawalawe reservoirs respectively. Using his figures for 3 years stocking (1983-85) and two year harvest of rohu the high profitability is proved. The seed cost Sri Lankan Rs. 18 300, against an income of S.L.Rs. 344 280 from the sale of 34 428 kg rohu in Kandalama. In Uadawalawe, against a similar stocking cost of S.L.Rs. 27 495 the revenue was S.L.Rs. 541 590. Rs. 10/kg is taken as a modest sale price of rohu.

China

Reservoir fisheries is managed as culture fisheries in China. The "boom" in reservoir fisheries was induced by the massive stocking after the success achieved in induced hormone breeding. 1.3 billion fingerlings were stocked in 1984 when the catch was 175 000 t. In the following year it was 200 000 t (Lu, 1986). The size at stocking had a lot to do with higher survivals, recoveries and yields. With a large number of fast growing cyprinids available and the high yields from reservoirs, cyprinids will continue to monopolize the reservoir fisheries in China.

4. CONCLUSIONS

Stocking is a major input in increasing and sustaining fish yields from large water bodies. For the IPFC countries, fast-growing, large-sized carp species of the Indus-Gangetic and Chinese origin are suitable. They occupy all the trophic levels in reservoirs and lakes and in a number of situations lead to good fisheries. They supplement a poor stock and supplant inferior species. Ranching of carps in reservoirs is profitable in general. Under certain conditions *Oreochromis mossambicus* has contributed to good fish yields, mainly in Sri Lanka where in the absence of any native species of value this exotic fish monopolised the shallow ancient reservoirs. The better tilapias like *O. niloticus* and *T. rendalli* did not make the same impact. In other countries tilapias did not succeed to the same extent although they have been quite successful in the Philippines, Indonesia and Thailand under certain situations. In general, tilapia does have a role to play "in subsistence systems as a means of protein production in parts of the world where there is a high level of malnutrition, but a low level of technology ..." (Balarin and Hatton, 1979). In smaller reservoirs in Tamil Nadu, *O. mossambicus* has served this purpose very well. Good stocking of Indian and Chinese carps in selected reservoirs in Sri Lanka is expected to lead to establishment of carp fishery. With the exception of Indonesia the common carp has been a failure in reservoirs all over the region. In Indonesia, common carp is the major species in cage culture in reservoirs in Java.

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THE TRENDS OF THE SRI LANKAN RESERVOIR FISHERY WITH SPECIAL REFERENCE TO THE ROLE OF CYPRINIDS

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1. INTRODUCTION

It is often claimed that the Sri Lankan inland fishery, which is a reservoir fishery, is one of the best documented in Asia (Fernando, 1977), and should therefore logically provide useful information that would enable general assessment and guidelines to be developed for the reservoir fishery in the region. The Sri Lankan reservoir fishery is essentially a capture fishery confined to the man-made lakes, principally located in the region of the country which receives a rainfall of less than 187 cm/yr. De Silva (1983) considered this fishery to be rather unique because it is a fishery confined to a man-made water resource, its backbone is dependent on an introduced species (*Oreochromis mossambicus*), and the gear, crafts and mode of fishing are uniform through the fishery.

The reasons for the success of *O. mossambicus* are still not fully understood, but it has been pointed out by De Silva (1985) and De Silva *et al.* (1984) that it is not directly a result of lack of indigenous lacustrine species.

This paper will attempt to evaluate the present and future role of cyprinids in the inland fishery of Sri Lanka. In order to do so it will consider the types of water resources, and the concepts associated with stocking and related aspects. The relevance of carps in Sri Lankan reservoir fisheries in the traditional sense depends, to a large extent, on stocking and recapture.

2. RESERVOIR RESOURCES

Reservoir resources of Sri Lanka fall broadly into two categories:

(i) the perennial reservoirs, and
(ii) the seasonal reservoirs, commonly referred to as seasonal tanks.

The perennial reservoirs were further classified according to the extent of land irrigated, and the hydroelectric reservoirs which are located above 1 500 m elevation (Mendis, 1977). The perennial reservoirs range from a few hundred hectares to over 8 000 ha/surface area. The total available acreage is estimated at around 150 000 ha (De Silva, 1988). The majority of these reservoirs are shallow, and range in age from over 2 000 years to recent. The number of reservoirs which have a surface area over 2 500 ha is less than 15. The details of distribution of the major reservoirs district-wise are given by Fernando and De Silva (1984) and De Silva (1988).

The seasonal tanks are located in the midst of villages and are small, mostly less than 10 ha in surface area. They are built across micro-catchments (Udawattage, 1985). Most of the existing 10 000 or so of these seasonal reservoirs are in a state of disrepair. These reservoirs are very shallow, often not exceeding depths of 1.5 m to 2.0 m at full water level. They dry out for up to 3-4 months of the year. By virtue of their location around which day to day village activities take place, there is a considerable quantity of nutrient input from cattle and through human activities, and therefore the productivity of these reservoirs is relatively high.

3 STOCKING

Stocking is an activity whereby individual fish are added to an aquatic community from an outside source in order to enhance yield generally by altering the balance of the community or making up for lack of natural reproduction. The increase in yield will thus result from filling a vacant niche, or from supplementing natural recruitment of the same species already present. Stocking may also be used to control undesirable aquatic organisms and for some other purposes.

Major and minor carps in Sri Lanka require specific conditions for spawning. In reservoirs, the major carps need to be regularly stocked, and this applies also to some other riverine fish species which are now under lacustrine conditions of new reservoirs.

Li (1978) considered the stocking efficiency (SE), i.e. the ratio of the yield (kg ha-1) to weight stocked (kg ha-1) as a useful index. For Chinese reservoirs SE >10, 5-10 and <5 are considered as excellent, good and poor respectively (Li, 1988). This concept is valid when the stocking size is relatively large, e.g. >20 g. Apart from the southeast of the country, the rate of return of stocked fish is considered a useful index for assessing stocking success. 30-50%, 10-30% and <10% returns are judged as excellent, good and poor respectively.

4. THE ROLE OF CYPRINIDS IN THE SRI LANKAN INLAND FISHERY

The Sri Lankan inland water resource of importance for inland fisheries is primarily the reservoir water. The two major types of reservoirs, i.e. perennial and seasonal, differ significantly in their hydrology and limnology, and as a result the role of cyprinids in the respective fisheries of the two types of reservoirs is different, and will be considered here separately.

4.1 Perennial reservoirs

4.1.1 Cyprinid fauna

The perennial reservoirs represent the main inland water resources. They have their own cyprinid fauna which was largely neglected both by scientists and fishermen until recently. Of the 25 species of indigenous cyprinids, two are marsh dwelling and one is found in the floodplains (De Silva, 1987). The rest are riverine. The general paucity of lacustrine species in Asia has been highlighted by Fernando (1980). All Sri Lankan indigenous cyprinids fall into the category commonly referred to as minor cyprinids, as opposed to the major carps which include the Chinese grass, bighead, silver, mud and black carps and the Indo/Gangetic rohu, catla and mrigal: this division is a matter of convenience based arbitrarily on the maximum attainable size.

Ten species of indigenous cyprinids have been recorded in the perennial reservoirs, of which at least two, *Barbus sarana* and *Labeo dussumieri*, are landed in the commercial catch as a by-product of the existing fishery (De Silva, 1983; Table 1). Only one exotic carp is documented to be caught in commercial quantities, and only in two reservoirs which have been very heavily stocked (Illukkumbura, 1986).

Table 1

Cyprinids recorded from Sri Lankan perennial reservoirs

Species	Authority
Indigenous species	
Amblypharyngodon melettinus (Ham.-Buch.)	b, c
Barbus chola (Ham.-Buch.)	b, c
B. dorsalis (Jerdon)	a, b, c
B. filamentosus (Val.)	b, c
B. sarana (Ham.-Buch.)	b, c, d, f, **
B. ticto (Ham.-Buch.)	p
Danio aequipinnatus (McClelland)	b
Esomus danrica (Val.)	b
Labeo dussumieri (Val.)	a, b, c, d, f, **
Rasbora daniconius (Ham.-Buch.)	b, c
Exotic species	
Cyprinus carpio (L.)	c, f, p
Labeo rohita (Hamilton)	c, f, c, *
Ctenopharyngodon idella (C. et V.)	f
Cirrhinus mrigala (Ham.-Buch.)	f
Aristichthys nobilis (Richardson)	p.

a - Fernando and Indrasena, 1969; b - Schiemer, 1983; c - De Silva and Sirisena, 1987; d - Amarasinghe, 1987; Illukkumbura, 1986; f - Amarasinghe and Samarakoon, 1989; p - personal observations; commercially landed, e.g. contribute over 5% - **; <1% - * in some reservoirs

4.1.2 Natural spawning of cyprinids

Spawning of any of the indigenous cyprinids or exotics has not been reported from any of the reservoirs in Sri Lanka. The spawning requirements of Labeo dussumieri seems to be very complex (Smith and Jiffry, 1986), and so are the conditions required for spawning of Indian major carps (Sinha, Jhingran and Ganapathi, 1974). It was deduced by De Silva (1988) from data from Sreenivasan (1984) that there is no evidence to believe that the Indo/Gangetic major carps spawn south of 12°25'N.

4.1.3 Role of exotic carps

The Indian major carps and Chinese carps introduced into Sri Lanka are successfully bred artificially (Weerakoon, 1979; Balasuriya *et al.*, 1983). Carps have been stocked into major perennial reservoirs since 1960. Since 1983, four reservoirs have been stocked more intensively (Table 2).

Table 2

Summary of stocking of exotic carps into the major reservoirs of Sri Lanka

Reservoirs/Years	Species	Total number	ha^{-1}	Source
All/1968-81	n.d.	1 900 094	n.d.	De Silva, 1988
Kandalama/1983-85	L.r.	305 000	441	Illukkumbura, 1986
Udawalawe/1983-85	L.r.	458 250	136	- do -
Maduruoya/1983	A.n.	331 000	53	De Silva, 1988

n.d. - not defined; L.r. - L. rohita; A.n. - A. nobilis

De Silva (1988a), who reviewed the stocking practices, concluded that in view of the low returns and the need to utilize fingerling production for the seasonal tank programme it would be futile to stock the large perennial reservoirs with exotic Indian and Chinese carps. Until recently, exotic carps were not caught in appreciable quantities and therefore did not appear in the landing statistics, although it is not rare for a few sporadic fish, in particular L. rohita (weight 750 to 1 250 g), to appear in catches in some reservoirs (personal observation).

Illukkumbura (1986), on the basis of stock estimates and fishery statistics from two reservoirs, attempted to show that it is economically feasible to stock major reservoirs with L. rohita. The stocking efficiencies, calculated using Li's (1988) ratio, are excellent (Table 3). However, the percentage return is very poor and shows poor economics of stocking of this reservoir. The contradictory results are difficult to explain, unless there is an error in the yield estimates. Therefore, the study seems to prove that stocking of L. rohita is not economically feasible in Sri Lanka, or is far from conclusive as claimed to be by Illukkumbura (1986).

Table 3

Calculated stocking efficiencies (SE) for *L. rohita* in two reservoirs, assuming that a 5 cm fingerling at stocking weighs 10 g, for data from Illukkumbura, 1986

Reservoir	Stocked (Kg ha^{-1})	Yield (kg ha^{-1})	SE	% Return
Kandalama	4.41	49.82	11.3	3.50 (2 - 4.3)
Udawalawe	1.36	16.06	11.8	7.45 (2.71 - 12.18)

4.1.4 Indigenous carps

Until recently it was generally accepted that in most of South Asia, due to the paucity of suitable lacustrine species in the indigenous fauna, and also species suitable for stocking the development and sustenance of the reservoir fisheries depended on the introduction of African cichlids (Fernando, 1980). It is conceded that the African cichlids have and will continue to play a major role in the reservoir fisheries of most nations in Asia, notably in Indonesia (Hardjamulia and Suwignyo, 1988), Thailand; Bhukaswan and Chookajorn, 1988), and in Sri Lanka (De Silva, 1985a).

The gradual development of fisheries, based on indigenous species in some reservoirs, such as the fishery for the clupeid *Clupeichthya aesarnensis* in the Ubolratana reservoir in Thailand, have begun to turn attention to alternative exploitable fish resources in reservoirs. In a few Sri Lankan reservoirs small-scale fisheries for the river sardine *Danio aequipinnatus* was practised from early days of the fishery (De Silva, 1985). However, experimental fishing with multimesh monofilament gill nets initially and later surveys with commercial size gill nets of 15 and 28 mm stretched mesh (De Silva and Sirisena, 1987; De Silva and Sirisena, 1989; Sirisena and De Silva, 1988, 1989) have shown that:

(i) small sized adult minor cyprinids inhabit relatively deep waters, overlapping there with the adult *O. mossambicus* on which the current commercial fishery is based;

(ii) small meshed gill nets in the deeper water do not catch young or pre-recruits of *O. mossambicus*;

(iii) the catch curves for the minor cyprinid species fall into two groups with optimum mesh sizes of 15 and 28 mm; and

(iv) a selective fishery for minor cyprinids could be effectively introduced.

De Silva and Sirisena (1989) used the ratio of minor cyprinids and *O. mossambicus* caught in the commercial scale trials (Table 4) as indices of the relative abundance of the two groups. Based on the commercial catches of *O. mossambicus* in the reservoirs and using the indices of relative abundance, the potential yield of minor cyprinids were estimated (Table 5).

Table 4

The mean yield of *O. mossambicus* (O.m.) gilled in the multi-mesh gill net trials (meshes >75 mm); De Silva and Sirisena, 1987) and that of minor cyprinids in the commercial scale trials in a piece of netting of 50 m long and 1.5 m high, and the ratio between the two yields. In the case of minor cyprinids (M.cy.) the appropriate mesh size is given in parentheses. The ratio between the two yields is considered as an index of relative abundance of the minor cyprinids in relation to *O. mossambicus* (from De Silva and Sirisena, 1989)

Reservoir	Yield (kg 50 per net) 1/		Ratio
	O.m.	M.cy.	
Badagiriya	-	2.97 (15 mm)	-
Lunugamwehera	-	4.65 (15 mm)	-
Muruthawela	0.46	2.80 (28 mm)	6.1
Ridiyagama	0.32	2.10 (15 mm)	6.6
Tissawewa	1.20	1.51 (15 mm)	1.25
Yodawewa	0.86	4.52 (15 mm)	5.25

1/ length of net = 50 m

Table 5

The potential yield estimates for minor cyprinids in the different reservoirs based on the existing commercial fishery data (from De Silva and Sirisena, 1987) and the ratio given in Table 4 and as explained in the text

Reservoir (ha)	Commercial fishery		Minor cyprinids	
	kg ha-1	tons yr-1	kg ha-1	tons yr-1
Badagirlya (482)	476	220	2 191	1 056
Lunugamwehera (3023)	132	400	635	1 920
Muruthawela (516)	15	3	35	18
Ridiyagama (888)	193	166	1 234	1 096
Tissawewa (234)	648	127	679	159
Yodawewa (488)	157	62	668	326

On this basis it is estimated that the mean potential yield of minor cyprinids would be about 907 kg ha-1 yr-1 and that a potential total yield of 90 700 t yr-1, or approximately three times that of the existing fishery, is possible.

Even though the projections are high it will not be advisable to commence a full-scale fishery at once. A detailed monitoring of the fishery will be needed to assess the long-term effect of the harvesting of minor cyprinids on their populations and on the other species. The use of small mesh sized gill nets will have to be also closely monitored and their numbers probably limited. Seining should be prohibited.

Another question that needs to be addressed is whether the produce of such a fishery would be suitable for human consumption. The small cyprinids cannot be transported over long distances due to their rapid spoilage, which also prevents their long storage. However, those fish which are not consumed directly could be sun-dried or used for fish meal.

The initiation of a fishery based on indigenous minor cyprinids in some ways refutes the notion of Fernando and Holcik (1982) that indigenous, riverine fish species are incapable of effectively colonizing and supporting a fishery in lacustrine habitats. This notion has already been proved wrong with respect to the fishery for the clupeoid C. sesarnensis in Thailand. It should be noted that the clupeoids occupy the pelagial of large reservoirs, and therefore the fisheries for minor cyprinids, which are semi-pelagic, would differ from these in some aspects.

4.2 Seasonal reservoirs

De Silva (1988a) summarized the results of preliminary stocking trials of some of the seasonal tanks for the growth periods of 1979/80, 1980/81 and 1981/82. The main points that emerged from this evaluation were:

(i) the indigenous minor cyprinid Labeo dussumieri uaed in the culture did not perform well, showing slow growth and giving poor returns;

(ii) the yields were variable between reservoirs and within a reservoir between years: they ranged from 18 to 1961 kg ha-1 between reservoirs and within any one reservoir from 327 to 1961 kg ha-1;

(iii) the yields of the exotic Chinese carps were variable specieswise between reservoirs and between growth seasons; but these carps fared best of all carps tested.

During the 1983/84 growing season Chandrasoma (1986) followed limnological parametera of 10 seasonal tanks. This study confirmed the relatively high productivity of these water bodies, with the mean chlorophyll a and photosynthetic production ranging from 8.4 to 48.45 g 1-1, and 0.75 to 4.25 g cm-2 day-1 respectively. Chandrasoma did not deal with the absolute number of returns of each species nor their growth. He concluded that the percent return of the stocked exotics carps was high with the zooplankton feeders (bighead and catla), detrital feeders (mrigal and common carp) and rohu dominating in that order in the catches. The contribution of grass carp to the final yield was generally low (<3%).

5. CONCLUSIONS

The reservoir area in Asia is increasing rapidly and at present is estimated to be 5.563 x 10 ha (De Silva, 1988b). For example, in Nepal it is projected to increase soon from 6 000 ha to 15 220 ha (Pradhan, 1988). The reservoir fisheries in most countries are recent even though, as in the case of Sri Lanka, the reservoirs may have been present for many centuries.

The reservoir fishery development is a low cost activity, and apart from its importance as an additional source of protein, mostly to the poor, it remaina economically attractive. It is in this context that further developments which lead to an enhancement of the fish yields have to be considered. Stocking is a costly exercise. In countries in which the stocked species are unlikely to be supplemented with natural recruitment, such as is the case of the major Indian and Chinese exotic carps in Sri Lankan major reservoirs, and where the probabilities of returns are less than 5% or stocking efficiencies are below 40%, it would be unwise to continue stocking these reservoirs.

The reasons for lack of objectivity with reapect to strategies concerned with stocking, in my view, are primarily the lack of accepted standard parameters for evaluating success of stocking. It is therefore necessary to evolve acceptable parameters for evaluating stocking success. Such parameters which are adopted to objectively assess stocking success, e.g. stocking efficiency, should also define its limit of utility. If fry or larvae are stocked, even a return of a few large individuals will result in a high stocking efficiency, thereby giving an erroneous picture. The importance of a species or a group of species in reservoir fishery development is likely to be dependent on the reservoir hydrology and therefore we need a reasonable system of classification of reservoirs for fisheries purposes. The lack of such a system at present limits the development of predictive models, and therefore adoption of effective managerial measures for the fisheries, with the consequence of not yet being able to realise the potential optimal yields from most reservoirs.

Present data indicate that the exotic Chinese and major Indian carps have no positive impact on the fishery of major perennial reservoirs in Sri Lanka. However, it is becoming evident that the indigenous minor cyprinids have a major role in enhancing the fish yields in these reservoirs: two to threefold increases in yields are predicted with selective fishing for these cyprinids. These new developments refute the opinion that the paucity of lacustrine species in Southeast Asian regions has necessitated the introduction of African cichlids to effectively utilize the reservoirs for fish production (Fernando, 1980; Fernando and Holcik, 1982). The African cichlids will continue, at least for some time, to have a strong impact on the reservoir fisheries in Sri Lanka and in other tropical countries. The recent developments indicate that the smaller cyprinids do adapt to lacustrine conditions, although they still need to undertake a migration into rivers to spawn (De Silva, 1983a; Smith and Jiffry, 1986). Fisheries for the already established African cichlids and riverine, indigenous, species which have successfully colonized the lacustrine habitats can co-exist, and therefore do not call for any further introductions to enhance fish production.

The Sri Lankan situation has proved that the exotic Chinese and Indian major carps, notably grass, bighead and silver carps, and rohu, mrigal and catla have an important role to play in the development of the fisheries in seasonal tanks, where essentially an extensive culture system is practised. For reasons that are not immediately apparent the indigenous minor cyprinid species, in particular Labeo dussumieri, do not establish themselves well in seasonal reservoirs where the cichlids also do not do well. The Sri Lankan experience, as well as that from other countries in Asia, also indicates the need to arrive at standardized criteria for assessing the stocking success in perennial reservoirs.

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GOBINDSAGAR RESERVOIR: A CASE STUDY ON THE USE OF CARP STOCKING FOR FISHERIES ENHANCEMENT

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1. INTRODUCTION

Located in northern India, Himachal Pradesh, the Gobindsagar Reservoir 31° 25' North, came into existence by impounding the water of the river Sutlej (Fig. 1).

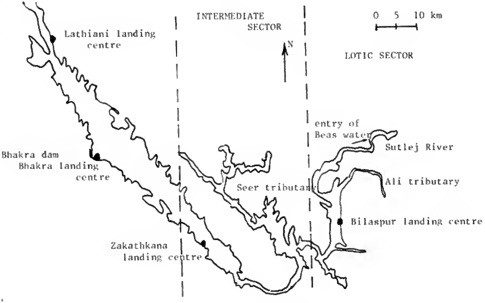


Fig. 1. Gobindsagar Reservoir

Originating on the Tibetan plateau from Mansrovar Lake situated at an elevation of 4 572 m, the Sutlej River flows from north-east to south-west. The river, receiving waters from glaciers, cuts 915 m deep through the plateau and later enters India after traversing a distance of 320 km in the Tibet Autonomous Region. Spiti River is the largest tributary of the river Sutlej and joins the Sutlej near Pooh. Down to Wantu, the river water is mainly represented by snow-melt. Wantu more or less demarcates the boundary between the rainfall zone and the dry zone of the catchment. From Wantu to Kashol the river flows between hills which have a rainfall ranging between 90-165 cm/yr. From Kashol to Bhakra are the Shivalik hills, and the river here is at its widest. Important tributaries (khuds) such as Lunkharkhud, Seerkhud, Gambharkhud and Alikhud enter directly the Gobindsagar reservoir. These tributaries bring voluminous discharges during the monsoon. Downstream of the reservoir the Sutlej River joins the Beas River at Harike and enters Pakistan. Gobindsagar Reservoir has the appearance of a highly flattened crescent . Its bed is littered with stones, boulders and tree stumps.

The reservoir catchment area is 56 980 km². At full supply level (FSL), the reservoir has a surface area of 16 867 ha while at the minimum dead storage level (DSL) it is 5 063 ha. The average surface area (mean of FSL and DSL) is about 10 000 ha. The annual water fluctuation varies between 41 m and 61 m, the maximum amplitude is 70 m. The total length of the reservoir is 168 km with the widest stretch of 6 km near the dam. At full reservoir elevation of 515.11 m above sea level (a.s.l.) it extends over three zones, i.e. Zone I (Lunkarkhud - 4 807 ha, 28.5%), Zone II (lentic zone - 5 585 ha, 34.8%), and Zone III (lotic zone - 6 198 ha, 36.7%).

The annual inflow into the reservoir varies between 4.4 and 8.0 million cusecs, while the outflow varies between 4.9 and 7.0 million cusecs. During the period 1983-87 the water level of Gobindsagar ranged between 450 to 507 m m.s.l. The average monthly level of the year was 485 m (1983), 479 m (1984), 482 m (1985), 446 m (1986) and 486 m (1987). The inflow was lowest in February-March and highest in July. The inflow commences with the influx of snow-melt water and subsequently continues in July-August in the runoff from monsoon rains. The outflow of the reservoir is highest during July and lowest in February.

2. PHYSICO-CHEMICAL ENVIRONMENT, PLANKTON, BENTHOS, PERIPHYTON

2.1 Soils

A study was conducted by the Central Inland Fisheries Research Institute, Barrackpore under the "All India Coordinated Project on Ecology and Fisheries" of Gobindsagar Reservoir. The basin soil during the pre- and post-monsoon months is alkaline and silty. The soil is poor with respect to both nitrogen (13.6-15.2 mg/100 g) and phosphorus (0.49-0.51 mg/100 g) (Table 1). The organic carbon is also low. The soil differs considerably in different zones with respect to physical and chemical features. In the intermediary sector the percentage of silt was high with equal proportion of sand and clay, while in lotic and lentic sectors clay was comparatively high. Chemical features showed sectoral differences. The organic carbon, available nitrogen and phosphorus also varied in the different sectors. However, the basin soil seemed to have very little impact on the quality of water as the latter mainly derives the nutrients from the catchment area.

Table 1

Physico-chemical parameters of the basin soil of Gobindsagar

	Pre-monsoon		Post-monsoon	
	1981-82	1982-83	1981-82	1982-83
Soil texture				
Sand (%)	21.1	20.8	33.6	33.9
Silt (%)	42.3	43.2	39.8	39.2
Clay (%)	36.6	36.0	26.6	26.9
Chemical psrameters				
pH	8.2	8.2	8.0	8.1
Organic carbon (%)	1.76	1.74	1.43	1.39
Available nitrogen mg/100 g	15.1	15.2	14.2	13.6
Available phosphorus mg/100 g	0.49	0.49	0.51	0.51

2.2 Water quality

The water of Gobindsagar Reservoir is generally clear during post-monsoon and winter months, but the transparency decreases from March onwards, till July (rainy season). Water temperature of the reservoir varies between 13.5°C and 31.6°C (Rao, pers.comm.). Before entering the reservoir the water temperature of the river Sutlej varies between 8°C and 25°C. Table 2 gives comparative informstion on the differentiation of water temperatures in different zones:

Table 2

Surface water temperature in Gobindsagar Reservoir

Time	Upper part of lotic zone 29.4.79	Bilsspur lotic zone 18.4.79	Upper part of lentic zone 22.4.79	Lentic zone 27.4.79
08.00	16.5°C	16.5°C	23.0°C	27.0°C
09.00	17.0°C	17.0°C	23.5°C	29.5°C
12.00	17.0°C	25.0°C	30.0°C	32.5°C
16.00	17.0°C	30.5°C	30.0°C	34.5°C
20.00	16.5°C	20.0°C	30.0°C	34.5°C
Mean	16.8oC	21.8°C	27.9°C	31.6°C
Air temperature (range)	21.8-38.5°c	16.5-36.5°c	19.0-36.0°c	24.0-39.5°c

The water of Gobindsagar reservoir shows a strong to weak thermocline during different months of the year in all the zones. Epilimnion may be limited to the top 2 m depth, with metalimnion extending from 2 to 6 m depth. Below that the water is homothermal. At other times, the depth profile shows the existence of warm water layer down to 50 m. Strong chemical stratification follows the temperature stratification and is the characteristic feature of the reservoir.

There is also a longitudinal zonation. In lentic zone, the temperature varied from 24.5° at surface to 18.6°C at 25 m depth, dissolved oxygen decreased from 8.4 to 6.5 mg/l at 12 m depth, carbonate alkalinity from 7.6 to nil mg/l, phosphates increased from 0.05 to 1 mg/l and specific conductivity from 161 to 187 micromhos/cm at 12 m depth. Compared to this, in the lotic zone the temperature varied from 21.0 to 16.9°C at 25 m depth, dissolved oxygen decreased from 9.2 to 6.9 mg/l at 12 m depth, carbonate alkalinity from 6.8 to 1.6 mg/l, whereas phosphates decreased from 0.94 to 0.1 mg/l and specific conductivity increased from 109 to 214 micromhos/cm at 12 m depth. The mean values for different zones are given in Table 3.

Table 3

Mean values of selected physico-chemical parameters

Zone	Temp. °C	CO_2 mg/l	DO_2 mg/l	CO_3 mg/l	HCO_3 mg/l	Ca mg/l	SiO mg/l	PO_4P mg/l	Conductivity micromhos/cm
Lentic zone	23.4	2.9	7.6	6.1	64.3	22.0	3.4	0.06	162
Inter-mediate	13.5	9.5	8.1	0.3	70.2	62.3	2.1	0.08	186
Lotic zone	18.7	3.7	8.2	3.4	81.7	24.4	2.4	0.05	189
Beas 1/ water	14.5	3.0	10.1	-	84.8	7.6	1.6	0.05	118

1/ This water is diverted from the Beas River by Pandoh Dam and guided through a tunnel into Gobindsagar.

2.3 Primary production and plankton

The gross primary production of Gobindsagar Reservoir varied between 420 and 935 mg C/m^2/day at 0.5 depth, 555-795 mg C/m^2/day at 1.5 m depth and 225-765 mgC/m^2/day at 2.5 m depth. The corresponding net primary production values varied between 270-630 mg C/m^2/day at 0.5 m depth, 445-615 mg C/m^2/day at 1.5 m and 210-495 mg C/m^2/day at 2.5 depth. The average 24 hours primary production was 11 696 Cal/m^2/day. The magnitude of energy fixation differs considerably during different seasons of the year.

The annual average planktonic biomass ranges from 2.1 to 16 ml/m^3. The biomass increases from September onwards reaching the maximum in December and February. There are two peaks of plankton during the year with an indication of spring and autumn blooms. The ratio between zooplankton and phytoplankton, as estimated by various workers, is 1:6.5. The zooplankton dominates only in September and October, while in other months the phytoplankton is dominant.

Lentic sector is the most productive sector of the Gobindsagar with planktonic biomass ranging from 0.-75 to 6.32 ml/m^3 (1975-83). The biomass fluctuates throughout the year. In general, the sector shows two pulses, the primary in February-March and the secondary in June. The primary pulse of late winter and early spring was found to be associated with the proliferation of Dinophyceae, copepodes and cladocerans. The secondary pulse of the planktonic biomass was due to the bloom of different green algae. Phytoplankton numerically dominates over zooplankton. Average standing crop of planktonic biomass in the intermediate sector ranged between 0.8 and 3.9 ml/m^3. The annual abundance showed a binomic mode of fluctuation, the primary peak being in February-March and the secondary peak in August and November. The spring peak is contributed mainly by Dinophyceae bloom, while the second peak of post-monsoon is due to diatoms and rotifers. The lotic sector of the reservoir is the least productive in relation to planktonic biomass. The average standing crop ranged between 0.5 and 2.29 ml/m^3. This zone also showed two pulses - one during monsoon and one during December-January. A sharp decline in biomass during March-June may be attributed to the changing condition of the water body due to the increased inflow of river water into the reservoir.

2.4 Benthic fauna

During 1971-86 benthic fauna of Gobindsagar comprised of oligochaetes (58.8% by weight), culicids (22.3%), chironomids (12.5%) and molluscs (3.0%) (CIFRI, 1986). The average abundance (by number) of benthic fauna ranged between 116/m^2 in 1975-76 and 1 020/m^2 during 1982-83. The population showed a bimodal pattern of fluctuation with two distinct peaks, one in winter (January) and one in summer (May).

Studies on seasonal distribution of benthic fauna have shown that population is generally poor in the monsoon season while the post-monsoon season, during which the reservoir stabilises after filling with monsoon water, provides favourable conditions for growth of benthic life. The overall abundance of benthos was found to be high in the intermediate zone while moderate in the lotic zone and poorest in the lentic zone in view of gravelly and rocky bed.

The intermediate zone is characterised by the dominance of oligochaetes (Branchiura, Tubifex, Limnodrilus and Nais). The other components of the fauna are dipteran larvae, molluscs, ephemeropterans and nematodes. The average number (biomass) of fauna for 1980-81, 1982-83, 1983-84 and 1984-85 were 300 (0.375 g)/m^2, 1 002 (6.381 g)/m^2, 1 088 (6.098 g)/m^2, 997 (8.385 g)/m^2 and 309 (1.213 g)/m^2 respectively.

In the lentic zone the fauna is represented by oligochaetes, hirudineans, dipteran larvae, nematodes, molluscs and ephemeropterans. The average number (biomass) was 967 (1.755 g)/m² in 1980-81, 1 225 (11.818 g)/m² in 1981-82, 1 152 (15-421 g)/m² in 1982-83, 646 (7.095 g)/m² in 1983-84 and 89 (34.250 g)/m² in 1984-85.

In the lotic zone the bulk of fauna is represented by dipteran larvae (*Chironomus*, *Chaoborus*, *Culex*, Tubifera, *Ceratopogon*, *Probezzia*). Gastropods, oligochaetes and nematodes were sporadic. Oligochaetes mainly represented by *Branchiura sowerbyi* dominated (by number) over others in the whole reservoir and formed 56.27% of the total bottom fauna.

Oligochaetes and dipterans were found at all the depths down to 80 m in the lentic zone and down to 70 m in the intermediate zone. Dipteran larvae were present in the lotic zone down to 35 m; the benthic fauna biomass is increasing with depth. Oligochaetes were more abundant below 10 m depth and their abundance increased from 20 m onwards in the intermediate and lentic zones. The maximum was found in 10 m depth (3 000 individuals/m²) in the intermediate zone, and in 80 m (2 625 ind./m²) in the lentic zone. In general, dipterans were more oriented towards shallower regions with maximum abundance between 8 and 15 m. Molluscs were found from 6 m depth onwards and their maximum abundance was at 20 m - 60 m in the intermediate zone. They increased in number towards greater depth in the lentic zone and were at a maximum at 15-20 m and 40 m depth. Nematodes showed maximum concentration between 30-60 m in the lentic and 15-30 m in the intermediate zone.

2.5 Periphyton

Studies conducted during the period 1971-86 (CIFRI, 1986) showed a binomic pattern of fluctuation in the annual abundance of periphyton, with a primary peak during autumn and secondary in spring. Sudden eruption in summer flora was also evident in June. The autumn population seemed to be more regular and consistent, with a gradual increase in the population recorded from August and culminating either in October or November. The spring peak was recorded either in March or April. The eruption of periphyton recorded during June was due to the sudden outburst of cyanophytes and diatoms. Diatoms seem to regulate the abundance fluctuations in periphyton. They are generally followed (in order of their importance) by protozoans, cyanophytes and green algae. Xanthophyceae, Rhodophyceae and Euglenophyceae are less common to rare.

The diatoms were the only community collected down to a depth of 60 m. Protozoans, Euglena, Chlorophyceae and Myxophyceae generally prefer shallower water.

3. FISH AND FISHERIES

3.1 Fish Stock Composition

There are 51 species (subspecies, varieties) of fish in Gobindaagar Reservoir. These belong to nine families.

(a) Family Cyprinidae: Barilius bendelisis, B. vagra, B. barila, B. modestus, Oxygaster bacaila, Rasbora daniconius, Carassius auratus, Cirrhinus reba, C. mrigala, Crossocheilus latius latius, Catla catla, Labeo dero, L. dyocheilus, L. bata, L. calbasu, L. rohita, Cyprinus carpio var. communis, C. carpio var. nudus, C. carpio var. specularia, Schizothorax richardsonii, S. plagiostomus, Ctenopharyngodon idella, Hypophthalmichthys molitrix, Tor putitora, Garra gotyla gotyla, G. lamta, Puntius sarana, P. ticto, P. chola, P. punjabensis and P. sophore.

(b) Family Cobitidae: Botia dario, B. dayi, B. bindi, Botia lohachata, Noemacheilus botia, N. rupicola, N. montanua, N. kangrae and N. horai.

(c) Family Bagridae: Mystus seenghala.

(d) Family Schilbeidae: Clupisoma garua.

(e) Family Sisoridae: Glyptothorax pectinopterus, G. cavia.

(f) Family Belonidae: Xenentodon cancila.

(g) Family Ophiocephalidae: Channa gachua and C. punctatus.

(h) Family Mastacembelidae: Mastacembelus armatus armatus.

(i) Salmonidae: Salmo trutta fario.

The following are the commercially important fiah (in order of their abundance). They all belong to three families, i.e. the family Cyprinidae: Hypophthalmichthys molitrix, C. carpio var. specularis, Catla catla, Tor putitora, Labeo rohita, L. dero, L. calbasu, Cirrhinus mrigala, L. bata, L. dyocheilus; family Siluridae: Wallago attu; and family Bagridae: Mystus seenghala.

3.1.1 Indigenous carpa

A perusal of indigenous carps composition in the total catch from 1974 through 1987 indicates that their proportion was increasing until 1978. This has been followed by a decline, reaching the lowest level of 13.9% in 1987 (Fig.2). The decline was especially pronounced in Indian major carps and minor carps.

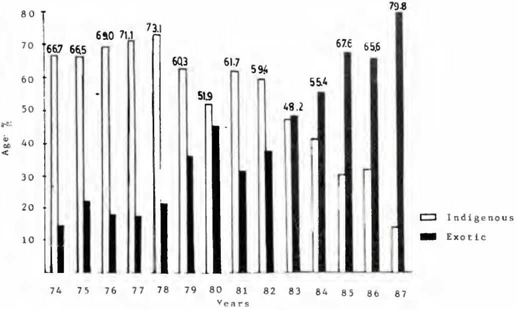


Fig. 2. Percentage Composition of Indigenous versus Exotic Carps

Indian major carps: All the four Indian major carp species, i.e. *Labeo rohita*, *Cirrhinus mrigala*, *Catla catla* and *Labeo calbasu* are present in the reservoir. *L. rohita*, a commercially highly valued fish, has undergone a steep decline in the catches since 1979. Its percentage composition in the reservoir increased progressively from 7.7% to 23.5% from 1974 to 1978, but later on slumped sharply to 1.2% (1987) mainly due to inadequate recruitment and wanton killing of brooders during their breeding seasons in 1977-82. A greatly sought after fish *Catla catla* suffered the same fate: the catches underwent an increase from 23% to 31% during 1974-77 in the total landings, but later started declining and during 1987 only 6.5% of the total fish landings were represented by *C. catla*. *C. mrigala* also initially increased from 2.2% to 16.8% (1976-79), after which a period of steep decline followed, reaching the lowest value of 0.6% in 1987. *L. calbasu* contributed minor proportion in the total catches, fluctuating between 0.03% to 0.5% during the last 15 years. In 1974 their percentage composition was 0.5%, while during 1987 it was 0.3%.

The total of the Indian major carps initially increased from 39.6% to 51.8%. Afterwards the catches started to decline and in 1987 the percentage composition reached a low of 8.7% .

Minor carps: The minor carps are represented mainly by the hill stream species L. dero, L. dyocheilus, L. bata, C. reba and Puntius sarana. The percentage composition of these fishes increased in the reservoir until 1982, and thereafter they started to decline. The percentage composition of minor carps reached an all time low in 1987 (5.1%).

3.1.2 Exotic carps

Silver carp, grass carp and common carp constitute the exotic fish fauna of the reservoir. A perusal of their percentage composition for the years 1974-87 indicates that in recent years exotic carps, in view of their prolific breeding, have monopolised the whole water body. While in 1974 they comprised 14.2% of the total landings (Figs. 2 and 3), by 1987 the percentage reached 79.6% (Fig. 2). The quantity of exotic carps harvested from the reservoir in 1974 and in 1987 was 24.3 t and 428.8 t respectively. A perusal of the catches for the last 14 years shows that since their introduction in the reservoir, the exotic carps have been increasing at the rate of 8.2% per year.

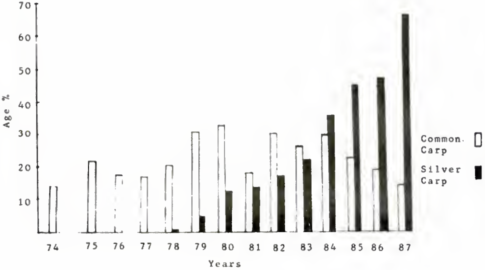


Fig. 3. Percentage Composition of Exotic Carps in the Total Catch

Silver carp (Hypophthalmichthys molitrix) got an inadvertent entry in the reservoir in 1971 by inundation of one of the fish farms of the department (Deoli Fish Farm) when 47 specimens ranging from 290-530 mm (0.5 to 2.5kg) were washed out. This species started appearing in the catches during 1977-78. Fishes of 300 mm size appeared in 1976. In 1977 there was a substantial catch of 10 000 kg of silver carp, although this accounted for only 1.4% of the total reservoir landings. The fish continued to reproduce and in 1987 silver carp landings reached a figure of 354 t, equivalent to 65.8% of the total. The maximum catches were achieved in the lotic sector of the lake where the water has a lower temperature.

In view of the wide feeding regime exhibited by silver carp which feeds on phytoplankton, zooplankton and organic debris, and its high fecundity (average of 167 000), this species appears to have ecological advantage over the other species. The experiments conducted by Alikunhi and Sukumaran (1964) have shown the superiority of silver carp over catla in growth rate, yield and production. The faster growth rate of this basically cold water fish in warmer biotope is to be expected in such poikilothermic animals. The study indicated that silver carp consumed far more food, i.e. three times that of C. catla, with silver carp having full guts throughout the year. Silver carp prefers zooplankton, especially rotifers and nauplii. According to Jhingran and Natarajan (1978) grazing of copepod nauplii by silver carps disturbs copepod life history and thus causes poor performance of C. catla. Further, the early maturation of silver carp in Indian biotopes provides a biological edge to this fish over C. catla as far as population expansion and establishment in the reservoirs is concerned. The silver carp multiply faster on account of early maturation in warmer ecotops and outstrip C. catla in numerical superiority.

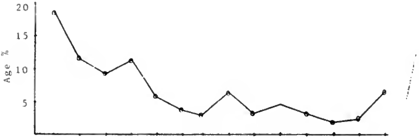
Only stray specimens of grass carp (Ctenopharyngodon idella) were encountered in the reservoir during the last 14 years. The non-establishment of grass carp in the reservoir may be attributed to the virtual absence of aquatic weeds.

Mirror carp (Cyprinus carpio var. specularis) constitutes an important fishery of Gobindsagar Reservoir. The fish has established itself well as indicated by its percentage composition in the total landings. The percentage composition ranged from 13.8 to 32.8 during the period 1974-87. In view of the massive seed production of this exotic carp, regular stocking is being carried out by the department since 1965. This species reaches an average size of 0.8, 1.4, 2.2 and 3.1 kg in its first, second, third and fourth year respectively. However, the reservoir being bereft of weeds which serve as substrate for sticking carp eggs, autostocking has not been observed in the reservoir.

There is a diversity of opinion pertaining to stocking of mirror carp seed in the reservoir. According to one school of thought the favourable limnochemical conditions prevailing in the reservoir do not necessitate the stocking of the mirror carp seed in the reservoir. According to others the absence of weeds in the reservoir is an obstacle for breeding of this fish, and makes the stocking of farm-reared fingerlings imperative.

3.1.3 Carnivorous fishes

The major carnivorous fishes of the reservoir are mahseer (*Tor putitora*) and *Mystus seenghala*. The percentage composition of both has declined over the last 15 years. In 1974 the total landings of these two species were 31.8 t (18.6%), whereas in 1987 it was 34 t (6.3%) (Fig.4).



Percentage Composition of Mahseer and *M. seenghala*

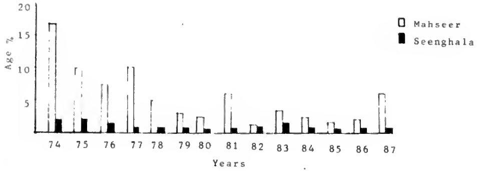


Fig. 4. Percentage Composition of Carnivorous Fish

The highly voracious fish M. seenghala has kept a low profile in the reservoir as reflected in the catch structure of the last 15 years. This may be attributed to poor availability of trash fishes in the reservoir. The composition remained almost stable for the last 15 years, fluctuating between 0.4 - 1.9%. The low numbers of these catfishes have indeed helped in fast propagation of Indian major carps during the initial years and silver carp in the post-1978 period. It is quite likely that the absence of spawning grounds may have limited reproduction of this riverine catfish in the reservoir. Tor putitora, the prized game fish, used to constitute a major fisheries in the river Beas, prior to the reservoir's impoundment. Its percentage contribution has dropped from 16.7 to 5.8% (1974 to 1987), but the yield in terms of landings has not markedly changed when comparing the catch from the first years of the impoundment, i.e. 1974-6 (37.8 kg) with 1987 (31.4 kg) (Table 4). The major factor which negatively affects this fish seems to be illegal fishing for juveniles. During 1987-88, 54 662 mahseer of less than 1 kg/weight each, accounting for 84% of the total catch, were harvested in the reservoir. This shows that the recruitment rate of this species is still high. However, fishing of immature fish may lead to a decline in stocks.

3.2 Fish yield, catch and effort

The yield (Table 5) ranged from 16.0 to 75.4 kg/ha. The minimum was in 1970 and the maximum in 1980. However, the direct comparison of these figures is not possible as until 1982 fishing was carried out for full twelve months, there being no 'closed season'. Only afterwards there was a ten-months fishing season. The closed season declared for the first time in 1983 (16 June to 24 July) was lifted in 1984 in view of the strong resentment by the fishermen community. The State Fisheries Department reimposed it in 1985 (1 June to 19 July). Since then it is being observed each year. The closed season coincides with the breeding season of the Indian major carps.

Table 4

Fish landings from Gobindsagar reservoir in 1974-87 (tonnes)

Year	Silver Carp	Minor Carp	Mahseer	Mystus seenghala	Indian Major Carp	Mirror Carp	Miscellaneous	Total
1974	-	24.0	28.7	3.1	67.7	46.4	0.8	171
1975	-	104.0	46.3	9.2	252.3	64.2	-	476
1976	-	91.0	38.4	8.0	258.8	92.7	19.6	509
1977	10.0	184.0	58.0	16.0	366.0	76.0	-	707
1978	13.0	209.0	67.0	7.0	364.0	94.0	-	754
1979	44.0	249.0	71.0	5.0	243.0	104.0	-	716
1980	88.0	213.0	77.0	5.0	202.0	122.0	-	707
1981	96.0	163.0	97.0	5.0	99.0	193.0	-	653
1982	103.0	170.0	81.0	7.0	56.0	145.0	-	562
1983	107.0	144.0	55.0	5.0	36.0	78.0	-	425
1984	223.0	113.0	45.0	2.0	55.0	67.0	-	505
1985	246.0	123.0	8.5	2.4	40.8	124.6	0.7	547
1986	176.0	71.0	7.5	1.7	33.2	87.2	-	377
1987	354.0	74.0	31.4	2.6	46.6	27.8	0.6	538

Table 5

Catch, yield and fishing effort in Gobindsagar reservoir (1970-87)

Year	Catch (t)	Yield (kg/ha)	No. of licensed nets	Catch index (1970 = 100)	Fishing effort index (1970 = 100)	Index apparent stock density Y/p
1970	160	16.0	100	1.00	1.00	1.60
1971	255	25.5	200	1.59	2.00	1.27
1972	277	27.7	280	1.73	2.80	0.99
1973	236	23.6	257	1.47	2.57	0.92
1974	171	17.1	321	1.06	3.21	0.53
1975	476	47.6	383	2.97	3.83	1.24
1976	509	50.9	710	3.18	7.10	0.71
1977	707	70.7	627	4.41	6.27	1.12
1978	754	75.4	617	4.71	6.17	1.22
1979	716	71.6	718	4.47	7.18	0.99
1980	707	70.7	770	4.41	7.70	0.92
1981	653	65.3	762	7.08	7.62	0.85
1982	562	56.2	748	3.51	7.48	0.75
1983	425	42.5	734	2.65	7.34	0.58
1984	505	50.5	663	3.15	6.63	0.76
1985	547	54.7	657	3.41	6.57	0.83
1986	377	37.7	671	2.35	6.71	0.56
1987	538	53.8	695	3.36	6.95	0.77
Total	8 575	857.5	9 913	53.51	99.13	16.61
Average	476.4	47.6	550.7	2.97	5.50	0.92
Range	160-754	16.0-75.4	100-770	1.00-4.71	1.00-7.00	0.53-1.60

In 1986 a low catch of 377 t - the lowest since 1975 - was recorded (Fig. 5). This was thought to be the result of lax management and of the widespread illegal and unaccounted fishing. This led the authorities to undertake a series of management measures, which resulted in increased catches in the following year. The catch figures show that during the period prior to the imposition of the closed season, up to 53% of the total harvest was used to be netted out during the breeding season, i.e. between mid-June and mid-August. The maximum killing of brooders was done during 1977 when 379 t of fish accounting for 53% of the total catch of the year was harvested during the breeding season. The average percentage of fish caught during 15 June to 15 August for the period 1976-82 was 37.8%.

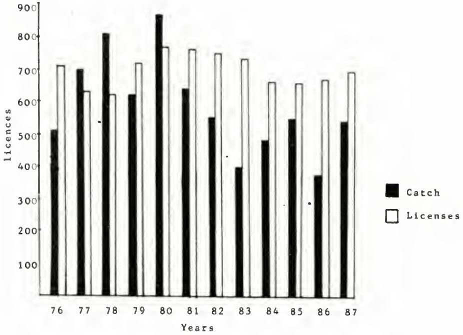


Fig. 5. Comparison of Catch (in tons) with Number of Licences Issued

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During the period 1969 to 1972 the upper limit of mesh size (measured knot to knot) was 75 mm. During 1973-74, encouraged by the improvement in catch composition, fishermen experimented with larger meshes up to 200 mm. In 1974-75 they used also meshes over 200 mm. This change altered the species composition and catch value. While during 1964-68 the predominant species was *Labeo dero*, in 1973 this changed to catches dominated by *Labeo dero*, *Tor putitora* and *Cyprinus carpio*, and after 1974-75 to catches dominated by *C. catla*, *L. rohita*, *C. carpio*, *T. putitora* and *L. dero*. Because of the dominance of larger fish in catch, the value of fish increased considerably. The proportion of nets with different meshes during different years was as follows (Table 6):

Table 6

Percentage frequency of different mesh sizes

Years	Mesh sizes (mm) 50-65	65-75	75-100	125-150	150-200	200-300	300-400	No. of nets
1964-68	100	-	-	-	-	-	-	50
1969-70	25	75	-	-	-	-	-	100
1970-72	10	40	50	-	-	-	-	160
1972-73	5	12	83	-	-	-	-	250
1973-74	2	10	83	2	1	1	1	300
1974-75	-	10	60	6	9	1	14	400
1975-76	-	15	32	4	15	9	25	550
1976-77	-	3	32	3	20	11	31	750
1978-79	-	-	30	20	20	25	5	800

The overall efficiency of nets with meshes more than 150 mm mesh was 1.59 times that of nets with 120 mm or less. Mesh sizes varied with season. During monsoon period large mesh sizes above 200 mm were effective while in winter and spring nets of mesh sizes less than 150 were of greater importance. The coefficient of efficiency for fishing efforts was 1.94 which was the maximum local efficiency at which gill nets were operated during 1977-79. The soundness of the logic was tested by Rao *et al.* (pers.comm.) who found that yield estimate was close to the recorded catch (Table 7).

Table 7

Estimated and recorded yield (1975-78)

Year ending March	Effort	Coefficient of fishing efficiency	Yield estimate	Yield in tons Estimate	Yield in tons Recorded
1975	1.00	1.00	1.00	260	237
1976	1.36	1.11	1.51	393	480
1977	1.85	1.17	2.16	561	547
1978	1.61	1.94	3.13	912	735
1979	1.76	1.94	3.41	887	742

The proportion of nets with meshes less than 125 mm decreased to 30% by 1978-79 (from 100% in 1972); at the same time nets with meshes above 150 mm have increased from 0% to 50% with a maximum of 62% in 1976-77. After 1977 even some nets of 400 mm mesh were used. Nets with meshes smaller than 100 mm caught mainly *Labeo dero*, *L. bata*, *P. sarana*, *T. putitora*, *Cirrhinus mrigala*, *Cyprinus carpio*, *Labeo rohita*, *Catla catla*. Nets 200 mm or more gilled mainly *C. catla*, *L. rohita* and mahseer and to a lesser extent *Cyprinus carpio*. It was observed that while many species varied in abundance in nets depending on mesh size, mahseer and common carp were captured by almost all mesh sizes. Because of this average landing became a function of mesh sizes.

3.3 Revenue

The revenue earned by the Fisheries Department from Gobindsagar Reservoir falls under three categories: (i) royalty at the rate of 15% of the price of fish caught, (ii) licence fee at the rate of Rs.50 for each gill net operated in the reservoir, and (iii) compensation realised from the poachers for conducting illegal fishing and sale of confiscated fish. For the total revenue realised during the last 15 years see Table 8.

Table 8

Revenue from Gobindsagar Reservoir (x Rs. 100 000)

Year	Royalty	Compensation	License fee	Fish auctioned	Total revenue
1978	2.88	0.09	0.31	0.05	3.33
1979	3.26	0.08	0.36	0.03	3.74
1980	3.61	0.17	0.39	0.05	4.22
1981	3.13	0.03	0.39	nil	3.39
1982	3.78	0.14	0.38	0.03	4.54
1983	2.79	0.17	0.37	0.03	3.37
1984	3.59	0.14	0.34	0.03	4.10
1985	5.39	0.20	0.33	0.04	5.96
1986	4.16	0.23	0.34	0.07	4.80
1987	5.87	0.23	0.35	0.04	6.49

3.4 Stocking (Fig. 6)

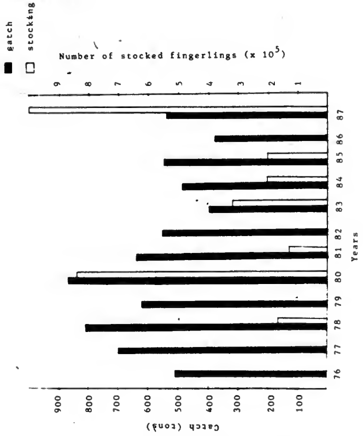

Fig. 6. Fish Yield and Stocking Rate

Prior to the construction of the dam the cold water of the upper reaches of the river Sutlej used to sustain 30 species of fish of which *Tor putitors*, *Labeo dero*, *L. dyocheilus*, *Schizothorax* sp., *Mystus seenghala* were the dominant ones. The main question which confronted the policy makers during the early years of fisheries development in the impoundment was whether the resident indigenous species of the Sutlej River would be able to effectively populate the lacustrine conditions of the reservoir formed by a high dam or whether new species are to be introduced to utilise the new habitat (Chakraborty, 1987).

It was a general consensus among the leading biologists that none of the indigenous fish would be able to offer viable commercial fishery and it was recommended that the reservoir should be stocked with Indian and exotic carps. The biologists pointed out that the riverine fish species would not thrive in the reservoir due to the drastic ecological changes. Taking this into consideration, during 1967-71 the State Fisheries Department stocked 3 500 gravid spawners and 0.6 million of fingerlings of Indian major carps ranging from 100 to 150 mm. By 1969, Indian major carps established themselves in the reservoir and started breeding. The stocking continued, mainly with the seed of mirror carp (Table 9). In order to produce the seed, the State Fisheries Department set up three fish seed farms, i.e. near the reservoir's site at Deoli (Bilaspur district), Nalagarh (Solan district) and Alsu (Mandi district).

Table 9

Stocking of Gobindsagar Reservoir (1976-88)

Year	Major carp			Mirror carp		
	Optimum stocking ('000 000)	Stocking done ('000 000)	Deficit percentage (%)	Optimum stocking ('000 000)	Stocking done ('000 000)	Ratio of overstocking
1976-77	1.6	-	100	0.4	0.63	1.5
1977-78	1.6	-	100	0.4	0.64	1.6
1978-79	1.6	0.17	89.4	0.4	0.87	2.2
1979-80	1.6	-	100	0.4	0.74	1.8
1980-81	1.6	0.84	47.5	0.4	0.92	2.3
1981-82	1.6	0.12	92.2	0.4	1.3	3.2
1982-83	1.6	-	100	0.4	1.4	3.6
1983-84	1.6	0.32	80	0.4	1.5	3.8
1984-85	1.6	0.20	87.5	0.4	2.0	5.0
1985-86	1.6	0.20	87.5	0.4	2.2	5.5
1986-87	1.6	-	100	0.4	2.3	5.7
1987-88	1.6	1.00	37.3	0.4	1.7	4.3
Range:		Nil - 1.00			0.63-2.3	

The Deoli fish seed farm was established in 1963. The farm has a total area of 4.5 ha and the annual production of 4-5 million seed. The farm has 16 nursery ponds and 2 brood stock ponds with the total water area of 1.4 ha. The main activities of the farm are production of mirror carp and Indian major carp seed, and training of the in-service staff and fish farmers. The breeding is undertaken in happas. A major portion of the seed produced is stocked in the reservoir, with the rest being sold to the private fish farmers.

Fish seed farm in Nalagarh has 18 nurseries and 2 rearing ponds. The total area is 6.8 ha. The production of the farm has remained static for several years and is mainly confined to the production of mirror carp seed of which in 1987-88, 1.28 million fry and 0.44 million fingerlings were produced. However, during 1987-88 Indian major carps were bred here successfully for the first time.

The Alsu fish seed farm has a water area of 1.3 ha in the form of 16 nurseries and one brood stock pond. The water quality is very suitable for both Indian major carp as well as for mirror carp. Heavy seepage is the major problem here and to prevent it the ponds have been lined with polythene. In 1987-88, 2.12 million fry and 0.44 fingerlings were produced.

4. RESERVOIR MANAGEMENT

During the first period of the reservoir existence, i.e. in 1964-75, the Fisheries Department used to issue licences at the rate of Rs.10 per gill net and fishermen were free to dispose their catches as they wished. During 1976 a new fishing policy was introduced and fishermen were organized into cooperative societies. The Central Fisheries Corporation was involved in the sale of fish outside the state while the state fisheries federation/societies were made responsible for marketing of fish within the state. The Central Fisheries Corporation, however, could not arrange for the transport of the increasing catches and later on stopped moving the fish from the reservoir.

A reservoir development committee which was established in 1976 took appraisal of the whole range of reservoir fisheries problems and made some drastic policy decisions in order to reorganize the fishing and marketing procedures. Grading of fish was initiated as the first step, followed by annually adjusted rates for each category of fish. For 1988-89 the following rates were fixed:

Type	Species	Price (Rs.)
A grade	*L. rohita*, *C. catla*, *M. seenghala*	13.90/kg
B grade	*C. carpio*, *T. putitora*, *C. mrigala*, *C. idella*	9.45/kg
C grade	*H. molitrix*	8.15/kg
D grade	All fishes less than 1 kg.	7.45/kg
E grade	Minor carps less than 1 kg	6.40/kg

Contractors for sale of fish were appointed from outside the state. The fish caught from the reservoir by the fishermen of primary societies are now brought to the fixed landing centres. The representatives of the Fisheries Federation receive the fish at the landing centres and daily record the category and species in the presence of the Fisheries Officer. The society also takes into account the complete record of the catches. The Federation then hands over the catch to the contractor. These contractors are jointly called by tenders at the beginning of the year and those who bid the highest price are given the contracts for the whole year. The contractor makes payment weekly to the Federation besides keeping a fixed deposit of Rs.500 000 - 600 000 as advance with the Federation. The Federation makes the payment once in 15 days to the societies after deduction of 15% royalty of the department and 5% of its own commission. The societies make the payment to the fishermen after deducting a marginal commission which varies from society to society and is fixed by the general house. The general house body is selected by the members of the society.

The federation acts as intermediary between the society and contractor for the society's sake. The federation is fully responsible for making payment to the fishermen and even if the contractor does not pay on time the federation has its own funds and is bound to make the payment to the fishermen from this fund.

To avoid conflict between the societies regarding the area of operation, the department has divided the reservoir into eight beats.

Fishermen who are members of the cooperative societies are issued licences through the cooperative societies by the respective fisheries officers of the landing centres. Presently there are 11 fishermen cooperative societies functioning in the Gobindsagar Reservoir with a total strength of 1 000 active fishermen. At Bhakra landing centre there are 4 cooperative societies, viz. Jayasree, Bhakra, Nakrana and Koshain. These are entrusted with catching fish at Bhakra and Nakrana landing centres. The Lathiani and Kutlehar societies are entrusted with catching fish at Lathiani landing centre. Mandli society has the right to catch fish only at Mandli landing centre while Bilaspur at Bilaspur landing centre. The catches of Zakatkhana landing centre are collected by three societies.

As earlier stated, the fish from the Gobindsagar Reservoir are caught by the primary societies and brought to the fixed landing centres. These landing centres are located at strategic points of the reservoir. The societies hand over their daily catch to the representative of the federation in the presence of the departmental representatives. The federation weighs the catch in the presence of the departmental representative, representative of the societies and representative of the contractor and later hands it over to the contractor. In case of any local demand it is mandatory on the part of the contractor to hand over 10% of the catch for local consumption while the rest of it he can sell according to his own choice. As seen from the above the first intermediary is Fishermen Cooperative Society. It changes its commission from the fishermen for smooth running of the society. The federation is a second intermediary which also charges its commission in view of its package services. Later comes the department, i.e. the third intermediary which also charges royalty from the transactions.

5. FISHERMEN AND THEIR ORGANIZATION (Table 10)

At present there are 1 034 active fishermen recruited from 5 000 oustees settled near the reservoir. This accounts for about 20% of the total fishermen population. Prior to the impoundment of the River Sutlej, a subsistence fishery of inconsequential nature existed in the rivers and streams, but with the formation of the reservoir the lucrative fishery started attracting a large number of fishermen and other oustees who lost their property with the emergence of the reservoir. The local fishermen who used to fish in shallow waters of rivers and streams with primitive gears found them ineffective in the deeper water of the reservoir. The Fisheries Department then initiated training in the use of deep water fishing gear and boats. The income of the fishermen operating in the reservoir inspired other oustees of various communities to adopt fishing as a profession and by 1978 the total number of fishermen reached 1 280. Besides direct employment to some 1 000 families, the state provided livelihood to about 1 000 additional families engaging in helping the fishermen, carrying/transportation, packing of fish, fishing crafts/gears repair, sale of fish, etc.

The fishermen in Gobindsagar are full-time licensed fishermen and members of cooperative societiea and have their own boats. On an average 40% of the fishermen have some education. The monthly income ranges from Rs.800 to 3 000. On an average, each fisherman has one boat, usually of the aize 15 ft x 3 ft x 2 ft, costing approximately Rs.2 000. The fishermen use mainly nylon gill nets. Each fisherman has on an average 3-4 gill nets of 100 to 140 mm mesh size which lasts about 1-2 years. The minimum allowable mesh sizes for economically important species are given in Table 11.

The State Department has initiated a series of schemes for the benefit of the fishermen fishing in the reservoir. 50% subsidy is provided by the department to a maximum of Rs.5 000 for the purchase of fiahing equipment, nets, boats and tents. The department also provides guidance in the purchase of these materials so thst it can befit the specification of the intenders. The scheme is highly popular and has helped in raising the total fish catch. A personal accident insurance scheme has been initiated on subsidized premium of Rs. 9/yr/fisherman. In case of fatal accident the insured person's family gets an amount of Rs.15 000. 75% of the premium is borne by the government agencies while 25% by the fishermen.

For losses, such as when nets or boats are blown away by a storm, a scheme has been initiated under which the fishermen are compensated to the tune of 25%.

Table 10

Fishermen, gear and economics

Year	No. of fishermen societies	Membership	No. of working fishermen	No. of gill net licences	No. of gill net licences issued per active fisherman	No. of boats used	Boats per fisherman	No. of illegal cases	Compensation realised (Rs.)
1985-86	9	890	534	657	1.2	640	1.2	350	19 597
1986-87	10	850	550	671	1.2	660	1.0	340	22 681
1987-88	11	1 034	575	696	1.2	590	1.0	384	22 654

Table 11

Minimum allowable mesh sizes for the major commercial fish

Species	Minimum mesh size (mm)
Tor putitora	300
Cyprinus carpio	300
Catla catla	450
Labeo rohita	400
Cirrhinus mrigala	300
Hypophthalmichthys molitrix	450
Ctenopharyngodon idella	450
Schizothorax spp.	250

5. DISCUSSION

The Gobindsagar reservoir offers examples of management as well as of mismanagement. Despite several management flaws, a yield of 8 618 t valued at Rs.86 million was obtained from the reservoir during the period 1974-87, with an average yield of 47.8 kg/ha/yr. The annual yield varied from 171 to 754 t/yr. The average yield fluctuated between 17.1 to 75.4 kg/ha against an all India average of 8 kg/ha (Shrivastava, 1985). Among the positive management decisions, the most prominent was to stock the reservoir with spawners and seed of Indian major carps as early as 1963-64. This helped in the establishment of Indian major carps and established a basis for lucrative fishery. The amendment of the State Fisheries Act 1976, the enforcement of mesh size regulations, the organization of fishermen under the cooperative fold, establishment of the Fisheries Federation, settling of fishermen during the initial stage from outside the state, initiation of fishermen welfare schemes, etc., were other well conceived measures which helped in boosting the reservoir fisheries activities and provided vocation to the oustees of the reservoir.

However, the failure of the authorities to observe proper closed season, to undertake judicious and regular stocking programmes, to arrange for guarding the spawning grounds, check on the mesh size regulation and to control wanton killing of brooders adversely affected the fish stocks. A considerable controversy persisted between the fishermen and the department since 1982-84 on the observance of the closed season, and the mesh size limits also remained a matter of dispute. It is estimated that during 1986-87 about 6 700 undersized yearlings of *T. putitora*, *C. mrigala*, *C. carpio* and *L. dero* of 300-700 g were harvested by the fishermen using nets of prohibited mesh size.

The inadvertent entry of silver carp into the reservoir and its role in depleting the indigenous species of the lake is a subject of debate. The physical and chemical water characteristics of the reservoir proved highly congenial for breeding silver carp, and in view of this prolific breeding the fish started monopolising the whole volume of the water body. The worst affected was *Catla catla* which, in view of its similar (and restricted) feeding regime, could not compete and declined. The *C. catla* might have fared better if the wanton killing of brooders had not been resorted to during the breeding season or had the adequate stocking been maintained by the authorities or proper closed season been maintained. As per the available information, during 1976-82, 1 550 t of gravid spawners of Indian major carps were harvested. Stocking made in the reservoir during this period hardly matched the demand of the reservoir. As per estimates (Shrivastava and Vathsala, 1984) the reservoir required to be stocked with 2 million fingerlings each year, but it was stocked on an average with only 0.3 million fingerlings/yr which is equal to 16% of the demand. The stocked seed was of s small size, i.e. 20-30 mm against the recommended 125-150 mm. No study was undertaken by the authorities on the survival of the stocked seed, but in all probability it seems to be very low. The major problem of the department in this connection is the inadequate rearing space on the existing three farms, which have a total area of only 4.6 ha. The department csn hardly produce 1.01 million of seed which accounts for 10% of the total demand of the state. Further, stocking was mainly confined to mirror carp. The stocking of Indian major carps has not only been inadequate, but it has also lacked regularity.

Maintaining a high sustained yield is the backbone of the reservoir fisheries management. The department gives it great attention and has a carefully developed monitoring system. At each landing centre, fisheries officers, field assistants, sub-inspectors and helpers have been posted, who weigh the landed fish and record them species by species. They also maintain strict surveillance on mesh sizes, apprehend poachers and take action against them. Further, in view of the long shoreline, the surveillance of the reservoir places a great demand on the limited man-power of the department. The situation becomes extremely acute especially during the closed season when fish are scarce in the markets and the prices of fish shoot up. The concentration of fish in the shallower areas for breeding makes them vulnerable to poaching. The Department sets up a number of field camps during the closed season at such vulnerable points to control the poachers. The Department has also set up flying squads in order to reinforce the surveillance. A conservation unit with a speed boat moves round the clock in the reservoir to protect the spawning grounds. In this way the Department has been able to control the illegal fishing in the reservoir to a considerable extent. The Himachal Pradesh government has enacted the Fisheries Act 1976 which gives full powers to the fishery officers to seize and remove fishing gear, and to forfeit and confiscate fish. At present about 5% of the fish catch is still taken away by the poachers.

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THE USE OF CARPS IN THE FISHERY MANAGEMENT OF RESERVOIRS AND LAKES IN INDONESIA

by

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1. INTRODUCTION

The importance of fish stocking of reservoirs and natural water bodies for increasing fish production, especially in view of the vast areas of natural bodies of waters and reservoirs in Indonesia totalling approximately 13 751 100 ha (Hardjamulia et al., 1986), is recognized.

Carps have been used in fishery management of reservoirs and lakes in Indonesia for (i) stocking of the bodies of waters either to increase fish catch or improve the fish group composition of the population; (ii) in pen culture; and (iii) in the recently developed culture in floating enclosures in reservoirs and lakes. No attempt has been made to use fish for controlling growths of aquatic weeds in reservoirs or natural waters. Lake Toba in Sumatera was the first lake to be stocked, i.e. in 1905 when common carp from Java was introduced there. Since then fish have been stocked into reservoirs and lakes on Java and Sulawesi, Maluku (Baluyut, 1983) and Irian Jaya (Howard, 1987). The stocking has not been conducted on a regular basis and has often been limited. Information on the number of fish stocked and the actual numbers or percentage of the stocked fish found in the total fish catch of the particular water body is poorly documented. Consequently it is as yet not possible to evaluate quantitatively the extent of contribution of fish stocking to the increase in the fish catch. One of the main reasons for limited stocking is that priority has been given to the use of fish fry for fish culture in ponds, pens and in the recently developed culture in floating enclosures in reservoirs and lakes. The fry supply is still far from sufficient even to meet the demand of fish culture.

This paper presents the available information on (i) combined contribution to the total yield of carps derived from stocking and those indigenous to the areas of individual water bodies, or that of the carps exclusively derived from stocking, (ii) use of carps for improving composition of fish stocks, (iii) use of carps for culture in floating enclosures in reservoirs and lakes.

2. MAJOR RESERVOIRS AND LAKES

2.1 Reservoirs

All reservoirs are multi-purpose water bodies, i.e. for electrical power generation, irrigation and flood control, and - in agreement with the policy of the government - also for fisheries. This is of importance especially in relation to the people resettlement programme when people have to leave villages in the future impoundment area.

Most of the reservoirs are located in the most densely populated island of Java. Presently there are at least 14 reservoirs with a total surface area of 53 000 ha ranging in individual surface area from 220 to 9 200 ha. The larger ones are the Jatiluhur (8 300 ha), Saguling (5 340 ha) reservoirs in West Java, Wonogiri reservoir (9 000 ha) in Central Java, Karangkates reservoir (1 500 ha) in East Java and Riam Kanan reservoir (9 200 ha) in South Kalimantan (Hardjamulia and Suwignyo, 1988).

Three types of reservoirs have been identified, notably field, irrigation and multi-purpose reservoirs (Hardjamulia and Suwignyo, 1988). The first two types are small in size, individually less than 500 ha, and they are discussed in this paper. The multi-purpose reservoirs have an area of over 500 ha, and are 30 to 100 m deep. Although a number of reservoirs have been constructed, only five of them have the individual area of over 5 000 ha (Table 1).

Multipurpose reservoirs which are constructed for hydroelectricity, flood control, water supply for irrigation, industry and municipal purposes, have a low fish productivity. For example, Jatiluhur reservoir is reported to have an average annual catch of 15 kg/ha (Hardjamulia and Suwignyo, 1988) and an estimated productivity potential of 12.6 to 30.2 kg/ha/yr. Saguling reservoir is estimated to have a fish yield potential of 14.1 kg/ha/yr (Hardjamulia et al., 1986). At least 34 species (including the exotic) have been identified in this reservoir. Among them are at least 11 species of cyprinids.

Fisheries management of multipurpose reservoirs faces many problems with respect to the biological and organizational aspects. The biological aspects include water quality which influences the life of fish. Certain reservoirs are poorly managed due to lack of coordination among the institutions concerned with the use of such reservoirs. Four of such reservoirs are located in Java.

2.2 Lakes

Lakes of Indonesia cover approximately 1 800 000 ha (Hardjamulia and Suwignyo, 1988). Large natural lakes are present on Sumatera, Nusa Tenggara, Sulawesi and Irian Jaya. The surface areas of some lakes are shown in Table 2. Some lakes are considered to have good prospect for fisheries (Hardjamulia et al., 1986).

The average annual yield of Indonesian lakes is 18 kg/ha. Lake Sentani in Irian Jaya yields 14.1 kg/ha/yr (Howard, 1987). Lake Toba has an estimated potential yield of 9.9 kg/ha/yr (Kartamihardja, 1985). The maximum sustainable yield of lakes and other natural waters is estimated to be 57 kg/ha/yr (Cholik et al., 1982). It is believed that there is a potential for increasing the current yield by stocking and introducing culture practices in the natural waters.

Table 1

Selected reservoirs of Indonesia and their characteristics

Location and name	Purpose	Volume ($10^6 m^3$)	Area (ha)	Drawdown (m)	Yield (kg/ha/yr)	Fish species
West Java						
Jatiluhur	FEI	2 970	8 300	32.0	15.0	T,C,L,H, S,P,M
Cirata	E	2 165	6 200	20.0		S,M
Saguling	E	982	5 340	20.0		T,C,L,H
Central Java						
Wonogiri	FEI	736	9 000	9.0		T,C.L,H
Cacaban	I	86				
Sempor	IE	52		29,0		
East Java						
Karangkates	FEI	343	1 500	26.0	50.0	T,C,I,H, M,S
Pacal	I	41	450		380.0	
Selorejo	FEI	62	400	24.0	250.0	T,C,L,P,S
Prijetan	I	10	220		50.0	
Lampung (Sumatera)						
Way Rarem	I	72		6.8		
Way Jepara	I	50				
South Kalimantan						
Riam Kanan	FEI	1 200	9 200	8.0		T,C,L,H, S,M
West Nusa Tenggara						
Batujai	I	17	890	5.0		

Purpose - (F=flood control, E=Electricity, I=Irrigation)
Volume - (storage capacity); Area = Surface area
Drawdown - Water level fluctuation; Yield = Fish yield
Fish species - T=tilapia, C=carp, L=lampam, H=hampala,
S=snakehead, P=*Pangasius* sp., M=*Macrones* sp.

Table 2

Surface area of some Indonesian lakes

Lake	Area (ha)	Location
Laut Tawar	7 000	Aceh Tengah in North Sumatera
Toba	110 000	North Sumatera
Maninjau	9 000	West Sumatera
Singkarak	11 000	West Sumatera
Diatas	3 600	West Sumatera
Dibawah	1 200	West Sumatera
Ranau	6 000	South Sumatera
Kerinci	6 000	Jambi in Sumatera
Tempe	9 000	South Sulawesi
Tondanao	6 000	North Sulawesi
Sentani	10 400	Irian Jaya
Total	179 200	

3. RESERVOIR MANAGEMENT USING CYPRINIDS

The objectives of reservoir fishery management are to increase the yield and to maintain a steady state harvest of fish at a level near the optimum productivity of the reservoir (Bhukaswan, 1980). Some methods of management have been known, such as (a) stocking or introduction of new fish species, (b) aquaculture; (c) fishery legislation to control or direct fishing effort; (d) environmental engineering (Welcomme and Henderson, 1976). Cyprinids are easily cultivated and fry of the common carp, tawes (P. gonionotus) and nilem (Osteochilus hasselti) are easily available. They have different food habits, some being omnivorous, others periphyton or plant feeders. So far, these three species are the only cyprinids that have been used in reservoir management in Indonesia.

3.1 Stocking

Juanda and Saguling reservoirs in West Java, and Wonogiri in Central Java belong to the group of larger reservoirs, which have the highest number of fish species, i.e. 20, 18 and 17 respectively (Table 3).

Table 3

List of fish species and their percentage in
the total yield for some reservoirs and lakes in Indonesia

Reservoirs/lakes Species	Juanda (Jatiluhur)	Saguling	Wonogiri	Toba	Karangkates	Selorejo	Bening	Tempe
Cyprinids:								
Puntius gonionotus 1/	46.9	8.8	24.3	+	+	+	19.7	70.0
Puntius bromoides	3.5	+	9.8	–	–	–	+	–
Puntius binotatus	+	+	+	+	–	–	+	–
Cyprinus carpio	+	10.4	0.8	2.5	+	+	+	+
Hampala macrolepidota	30.3	30.5	16.9	–	2.4	1.8	–	–
Labeobarbus sp.	–	+	–	–	+	+	–	–
Labeo chrysophekadion	+	–	–	–	+	+	–	–
Osteochilus hasselti	+	25.7	0.4	+	–	–	–	–
Mystacoleucus marginatus	+	8.8	+	–	–	–	–	–
Dangila cuvieri	–	–	5.8	–	–	–	–	–
Lissochilus sp.	–	–	–	+	–	–	–	–
Labyrinthici:								
Osphronemus gouramy	+	–	–	+	–	–	–	–
Ophiocephalus sp.	+	+	0.3	+	+	+	1.2	–
Anabas testudineus	+	+	+	–	–	–	–	+
Helostoma temmincki	+	+	–	–	–	–	–	8.0
Trichogaster sp.	+	+	–	+	–	–	–	20.0

Table 3 contd.

Reservoirs/lakes Species	Juanda (Jatiluhur)	Saguling	Wonogiri	Toba	Karangkates	Selorejo	Bening	Tempe
Bagridae:								
Macrones nemurus	11.5	+	41.2	-	-	-	-	-
Macrones nigriceps	+	+	0.6	-	-	-	-	-
Macrones micracantus	+	+	+	-	-	-	-	-
Cichlids:								
Oreochromis niloticus	3.6	+	+	+	10.6	6.0	+	-
Oreochromis mossambicus	+	+	+	96.0	86.0	90.0	79.2	-
Pangasidae:								
Pangasius pangasius	+	-	+	-	-	-	-	-
Clarias batrachus	+	+	+	1.0	+	+	+	+

Remarks: + = small percentage, negligible
- = not available

1/ Synonym = *P. javanicus*

Eight species of cyprinids were found in the above mentioned three reservoirs with a total yield of 80.7%, 84.2% and 58.0%, respectively. In Juanda reservoir carps contributed 81% of the total yield, of which *Puntius gonionotus* contributed 46.9%, followed by *Hampala macrolepidota*. The latter is the only carnivorous cyprinid, which becomes piscivorous when reaching adult size longer than 20 cm. *P. gonionotus* is an indigenous species of Juanda reservoir where it arrived from the river Citarum.

Saguling reservoir is located on the river Citarum, upstream of Citarum reservoir. The Saguling dam was completed in 1985 when the reservoir was also established. Although Juanda and Saguling reservoirs are on the same river, the difference in altitude and in water quality influence their fish composition. *P. gonionotus* constituted 8.8% of the population while *H. macrolepidota* had the largest population (30.5%), followed by *Osteochilus hasaelti* (25.7%). Common carp is an exotic species supposed to reach the reservoirs through streams and stocking. Common carp contributed 10.4% of the total yield which is the highest percentage for a species in the reservoirs in Indonesia. In two lakes in Irian Jaya, i.e. Lake Paniai and Anggi, common carp represents 84% and 100% of the total yield. In Saguling reservoir cyprinids represent 84.2% of the total yield.

In Wonogiri reservoir in Central Java, *P. gonionotus* is the dominant cyprinid (24.4%), followed by *H. macrolepidota* (16.9%). Cyprinids are also the major group comprising 58% of the total yield. However, the dominant species is a catfish *Macrones nemurus* (41.2%) which, for comparison, represents only 11.5% of the total yield in Juanda. In lake Toba *Oreochromis mossambicus*, with 96%, highly dominates the total yield. Common carp contributes only 2.5%. Both species are exotic. In the small reservoirs, Karangkates and Selorejo in East Java, cyprinids constitute a small proportion of the total while the stocked *O. niloticus* and *O. mossambicus* form about 96% of the total yield.

Common carp is highly preferred by the people of West Java, where Juanda and Saguling reservoirs are located. *P. gonionotus* is less favoured there, but in Central and East Java it is more preferred than common carp.

Tawes (*Puntius gonionotus*) and nila (*O. niloticus*) have been stocked into Juanda reservoir with the purpose of improving the fish species composition. The success of stocking is seen in the shift in the predator (P): prey (F) ratio from 65:35 in 1982/83 (prior to stocking) to 45:55 in 1985/86 (after stocking) (Hardjamulia *et al.*, 1986).

3.2 Culture

Common carp culture in floating enclosures provides job opportunity and generates income for the local people. Two types of culture have been practised in reservoirs: culture in pens and in floating enclosures. The latter type is more popular. It is widely practised by farmers and well developed in the Saguling reservoir in West Java. To a lesser extent it is also practised in the Jatiluhur (Juanda), Citarum and the smaller Lido reservoirs in West Java and in Riam Kanan reservoir in South Kalimantan. Common carp is the only carp which has been cultured up to the present, but it is expected that other species will also be cultured in reservoirs soon.

Carp culture in reservoirs has good prospects for several reasons:

(i) Reservoir areas with potential for fish culture are estimated to total some 50 000 ha, assuming that 1% of the area is suitable for culture. The number of reservoirs will increase in the future;

(ii) in general, water quality, particularly the dissolved oxygen content of reservoirs, is very good. Oxygen content usually exceeds 5 ppm which should give a feed conversion ratio of around 2:1 and good fish growth rate. The conversion ratio is lower than that in intensive carp culture in running water ponds which is around 2.5;

(iii) investment is relatively low compared to intensive fish culture in ponds. Construction of a floating net unit is simple consisting of bamboo raft and a floating cage of 7 x 7 x 2 m.

3.3 Experiments in reservoirs

3.3.1 Jatiluhur reservoir

The first experiment on fish culture in a floating net cage was conducted in Jatiluhur reservoir in 1972. This was later followed by other experiments conducted in Lake Lido in West Java, Lake Toba in north Sumatera and Lake Tondano in Sulawesi (Djajadiredja, 1983). In Jatiluhur an experiment was conducted to evaluate the use of a pelleted feed containing 30% protein for production of common carp in floating net culture. Three floating cages were used each measuring 7 x 7 x 2 m (= 1.5 m water depth). The common carp used for stocking ranged from 100 to 125 g, and it came from a breeder in Sukabumi in West Java. The initial stocking density was 294 kg of carp per net or 6 kg/m^2 of surface area. The fish were fed three times daily at daily feeding rate of 3% the fish biomas. After 4 months of culture an average total harvest of 1071.4 kg per cage was obtained giving a net production of 777.4 kg per net or 271.47 % of the stocked biomas. The average feed conversion value (FCV) was 2.38 and the average mortality rate was 1.09. The FCV was lower or better than commonly obtained in running water pond culture (Djajadiredja *et al.*, 1983). Economic analysis based on the result from 4 cages for one year showed:

(a) net income (gross income minus tax) = US $1 919 with a profitability index = 1.44 which was acceptable;

(b) internal rate of return = 36.35%; and

(c) pay back period of the cost of investment = 3.17 years.

Seed and feed costs contributed the major portion of the operational cost, amounting to 36.34% and 50.33% of the operational cost, respectively (Djajadiredja *et al.*, 1983).

It is interesting to add that this was part of a group of experiments intended to compare the use of common carp, nile tilapia and gurami (Osphronemus gouramy) for this type of culture. Nile tilapia showed better FCV and higher net production than common carp. Both species showed profitability index, internal rate of return and pay back period close to each other. Common carp is preferred by the people as compared to nile tilapia. Gurami in this experiment using only one net showed an unacceptably low profitability index of less than one (Djajadiredja et al., 1983), although it is the most preferred species for special occasions such as wedding parties in West Java.

3.3.2 Saguling reservoir

Floating net cage culture in the Saguling reservoir, West Java

The good prospects of this type of culture as a source of jobs and income and the recommendations of the Institute of Ecology (IOE) of Padjadjaran University Bandung (UNPAD) prompted the Provincial Administration of West Java to study the feasibility of this culture as an alternative to solve the resettlement problems of 3 100 families who had to leave their villages due to the construction of the reservoir. Over 96% of these families were not willing to move from the Saguling area. To implement the resettlement programme the state Electric Company of West Java requested the Research Institute for Freshwater Fisheries (RIFF), Bogor to conduct experiments in fish culture in floating nets, floating cages and pens in Lido reservoir, and later also a common carp and Nile tilapia culture in floating nets in Jatiluhur reservoir, both in West Java.

Good results obtained from both groups of experiments and transfer of the culture technology to 40 people of the Saguling area were soon accomplished through field training for 20 prospective fish farmers in Lido and the other 20 in Jatiluhur. These 40 people then served as a "nucleus" and had to transfer in turn the culture technology to other prospective fish farmers in Saguling areas, and both groups then formed a "People Plasma Nucleus" (PIR) culture enterprise system.

Experiments in the Saguling reservoir

Costa-Pierce et al. (1988) reported interesting results from the two experiments they conducted in the reservoir. The first experiment with four replicates duplicating the existing farmer system using a 7x7 x 2.5 m floating net used stocking density of 2.4 kg/m^3 of common carp of an average weight 71.8 g. Commercial feed (Comfeed) contained 24% protein and it was given three times daily at a daily feeding rate of 3% of the fish biomass for the culture period of 90 days. The production obtained was 1 070 kg (± 76 kg)/net/90 days, and it exceeded the carrying capacity of the system. They drew attention to their second preliminary experiment using a 9 x 9 x 2.5 m floating net, a lower stocking density of 0.5 kg/m^3 of common carp averaging 63 g and also fed for 90 days. This gave a yield of 976 kg/net/90 days. This yield was not significantly different from the mean yield of the first experiment, but in the second experiment using the lower 0.5 kg/m^3 stocking density there was a saving of two thirds of the amount of fish seed and a half of the fish feed. The results of the preliminary economic analysis were in favour of the 9 x 9 x 2.5 m with 0.5 kg/m^3 stocking density over the 7 x 7 x 2.5 m with 2.4 kg/m^3 stocking density, as shown in Table 4.

Table 4

Floating enclosure economics

Culture system	Total capital cost (US $)	Net Profit (US $)	Benefit to cost ratio
9 x 9 x 2.5 m floating net, 0.5 kg/m³ stocking density of fish of average weight 63 g, 90 days feeding period	297	399	2.2
7 x 7 x 2.5 m floating 2.4 kg/m³ stocking density of fish of average weight 71.8 g, 90 days feeding period	202	165	1.1

The importance of further research on optimizing carrying capacity of fish in the floating nets in the Saguling reservoir was stressed since fish seed and feed costs are the two largest operating costs in the stocking culture system.

Development of common carp culture adopted by farmers in Saguling reservoir

In a few months after the filling, the common carp culture in floating nets in the reservoir was already established. The present practice is to stock fingerling of around 100 g individual weight. The fingerlings are produced by rice field culturists in the Bandung area about 50 km from the reservoir. In contrast, common carp culture in pens and cages has not yet been developed on a large scale (Table 5). The major obstacle can be seen in the fluctuating of water level which sometimes results in water in the pens becoming too shallow or even to disappear. Cage culture has not been introduced because of its low productivity and difficulties in its management.

Table 5

Number of floating net units, pens and cages
and fish production in Saguling reservoir

Type of culture	1985	1986	1987	June 1988
Floating net				
Number of units	57	366	805	1 064
Total production (tons)	14.7	604	1 438	1 151
Pen				
Number of units	35	35	13	13
Total production (tons)	1.3	2.0	6.0	-
Cage				
Number of units	26	20	22	22
Total production (tons)				

One unit is a one 7 x 7 x 2.0 m (1.5 water depth) net.

Factors responsible for the success of the floating net culture in Saguling reservoir

There are several major factors responsible for the success of common carp in floating nets in the Saguling reservoir.

Regarding socio-economic factors, common carp is the most preferred species and in great demand in West Java. The eruption of Mount Galunggung in 1983 destroyed the fish culture areas in Garut district reducing the fish production for the market by around 30 000 t/yr (Bappeda, 1982). This shortage has helped the marketing of the carp produced in culture in Saguling reservoir.

Common carp culture in floating nets is more profitable than that in running water ponds because of the higher feed conversion efficiency leading to lower production cost in the former. Fish from running water ponds were sold wholesale in Bangung at Rp.1 800 (US $ 1.125/kg) whereas from floating nets for Rp.1 400 to Rp.1 500 (US $0.875 to US $0.938/kg) (Costa-Pierce et al., 1987).

Commercial fish feed is easily available although its price relative to the price of the fish harvest is presently not very favourable for the farmers.

Common carp is widely known as a hardy species which can grow well in a wide range of water quality. The reservoir has good water quality except when water upwelling deteriorates the water quality on certain days during the rainy season.

The configuration of the Saguling reservoir is also of importance. Saguling has a dendritic shape, with many bays which afford good protection for the floating nets from the direct action of wind and waves. This results in calm water suitable for placement of the nets. Our experience in the Jatiluhur reservoir has shown that direct wind and waves may damage floating nets. The banks of the Saguling reservoir are generally steep enough to allow placement of the floating nets near the road. The ring road constructed around the Saguling reservoir promotes easy access to the floating net areas facilitating transportation of fish and feed to the areas or fish harvest from the areas to the market. In the Jatiluhur reservoir no such road exists and this is one of the reasons why floating net culture has not been developed.

The Saguling reservoir has a nearby market in Bandung, the capital of West Java Province. There are other markets near the main roads and in Jakarta which has a population of around six million.

Problems with the floating net culture in Saguling reservoir

Although the floating net culture in Saguling reservoir has shown positive impact as a source of income and job opportunity, the fish culturists have been faced with several problems described below:

- Deterioration of water quality causing mass mortality of fish, sometimes occurred in rainy season. The deterioration was caused by water mixing in which the deoxygenated bottom water drastically reduces dissolved oxygen content in the whole water body. Such mixing occurred when there was a lack of sunshine due to heavy clouds lasting for up to three days. Lack of sunshine also reduced phytoplankton production which in turn lowered the dissolved oxygen content. In late July and August 1988, about 41 t of cultured fish died. The dead fish were sometimes sold at 20 to 40% of the price of live fish, but in some cases were not accepted in the markets.

- The price of feed for the common carp culture has been increasing more than that of the harvested fish. In 1985, the price of feed was Rp.350/kg while at present it is Rp.550/kg indicating an increase of about 57% in contrast to the increase of only about 4% in the price of fish over the same period. Presently there is no problem of feed supply as the existing seven feed companies can meet the feed demand. It seems, however, that feed supply constitutes a potential problem in the future in view of the fact that the raw feed materials such as fish meal and soybean meal are still imported.

- The fish seed supply for culture is not sufficient and not always available in the right time of culture.

3.3.3 Common carp culture in floating nets in Cirata reservoir, West Java

Cirata reservoir located downstream of Saguling reservoir was inundated in September 1987. Common carp culture in floating nets in this reservoir has been developing steadily. At present 42 units exist in the reservoir. Due to the better water quality and a better sited market, the authors believe that in time this culture will become competitive with that in the Saguling reservoir.

3.3.4 Common carp culture in Riam Kanan reservoir, South Kalimantan

Common carp culture in floating nets was introduced into Riam Kanan reservoir in 1984, but there has been little progress. On the other hand, cage culture of common carp downstream the Riam Kanan river has been developing rapidly and at present there are over 200 cages in this river.

3.3.5 Prospects for reservoir fish culture outside Java

The factors responsible for the success of floating net culture in Saguling mentioned above can be used as criteria of the economic feasibility of fish culture development in other reservoirs in Indonesia. There is a potential for development of floating net culture in provinces where common carp is a preferred species, and where reservoirs are present. Such conditions are in West Java, West Sumatera, North Sumatera and North Sulawesi.

One of the constraints to the development of intensive freshwater fish culture in the regions outside Java is the nonavailability of commercial fish feed or, where available, the price of feed is prohibitive. Presently, most fish feed manufacturers are located in Java.

4. LAKE MANAGEMENT USING CARPS

4.1 Stocking of lakes in Irian Jaya

All information as given below is extracted from a report by Howard (1987). This report deals with inland fisheries of Irian Jaya. Table 6 shows some information on the lakes in Irian Jaya.

Table 6

Physical and yield data on the lakes in Irian Jaya

Lakes	Altitude (m)	Area (ha)	Max. depth (m)	Actual yield		Potential yield	
				Total (t)	Average (kg/ha/yr)	Total (t)	Average (kg/ha/yr)
Sentani	70	10 400	52	147	14.0	200	19
Paniai	1 742	14 150	50	43	3.0	127	9
Tage	1 752	2 400	50	1.9	0.8	7	3
Tigi	1 640	3 000	15	9.6	3.2	15	5
Anggi Giji	1 800	2 000	70-80	6.0	3.0	18	9
Anggi Gita	1 870	2 500	70-80	3.75	1.5	7.5	3

Except Lake Sentani, the lakes are located in the highlands where approximately 60-70% of the rural population resides. Lake Sentani is the best accessible of the lakes. Most of the highland lakes and rivers are not fully exploited because of ignorance of fishing methods and because in some areas fish is not an acceptable item in the diet.

Some of the available water quality data are shown in Table 7.

Table 7

Water quality in lakes in Irian Jaya

Lakes	Surface temp. day-time (°C)	Air temp. daytime (°C)	Surface pH day-time	Secchi disk (m)	Water level fluctuation (m)	Dissolved Oxygen (mg/l)
Sentani	29 - 31.8	28.5-32.0	6.5-6.8	20.0-3.5	0.4	4-10
Paniai	22.0-24.0	14 - 21	6.5	2.4-4.6	3-4	*
Tage	25	?	?	?	?	**
Tigi	24-25	15 - 22	6.5-6.8	1.2-1.5	up to 2 m	?
Anggi	?	10 - 21	?	?	0.5	?

* Supports aquatic life
** Supersaturation in daytime. Serious depletion may occur during night.

Most of the lakes and some of the rivers have been stocked with fish. Table 6 indicates that Lake Sentani has by far the highest actual and potential yield, perhaps because of its high water temperature as compared with other lakes. The national average of fish yield in freshwaters is 19.2 kg/ha/yr (Indonesia, 1986). Except for Lake Sentani, species diversity is low in the highland lakes. In Lake Sentani the endemic species dominate amounting to about 95% of the landings. In the other lakes and in rivers there are only few endemic fish species, and introduced common carp is the big fish which contributes to the nutritional well-being of the people there. For the endemic and exotic species in the lakes see Table 8.

Carp stocking in Lake Sentani

Contrary to trends elsewhere, where exotic introductions have resulted in a reduction if not an elimination of indigenous species, in Lake Sentani the indigenous species form 95% of the landings, consisting mostly of snake head (93.8%). Common carp form about 6% of the annual catch. The carp caught by 1.5 cm meshed nets often weigh up to 10 kg, but those of 300-500 g size command better price at the local markets.

Common carp stocking in Lake Paniai

Common carp were introduced in 1939 by air drops. Since then several stocking programmes have been completed, the main ones being in 1964 and 1974 when Enarotali hatchery became operational. It is estimated that about 500 000 fry were stocked. Carp now form 84% of the landings. The bulk of them are small and immature. Sample measurements have shown two age groups which shows that carps spawn twice a year. The fish seem to grow slowly. It would appear that the introductions of common carp during the 1930s, 1960s and 1970s have produced a self-sustaining resource.

Table 8

Indigenous and exotic species in lakes of Irian Jaya

Lake	Indigenous species	Exotic species
Sentani	19 species (95% of the total landing), mainly Ophiocara aporus, Glossogobius giurus, Apogon wiehmani, A. besuforti	8 species (5%): Carps (C. carpio, P. gonionotus, P. orphoides), Helostoma temmincki, Trichogaster pectoralis, Osphronemus gouramy, Oreochromis mossambicus, O. niloticus. Common carp is frequently caught in mature condition
Paniai	Oxyeleotris fimbriatus, Cherax spp., Pila sp. 16%	Carps (a total of 100 000 introduced in 1939, 1964 and 1974); 84% of the total landings
Tage	O. fimbriatus	Carp (20 000 stocked); almoat 100% of the total landings
Tigi	O. fimbriatus, Cherax sp.	Carp (a total of 400 000 fry stocked in 1930, 1964 and 1972)
Anggi	No indigenous species reported	Common carp (stocked: 1973 - 10 000, 1984 - 13 000); 100% of total landing

Common carp stocking in Lake Tage

About 20 000 carp fingerlings from the Enarotali hatchery have been stocked. The total carp landings from this lake are estimated at 1.9 t/yr. Those caught by a long handled scoop net are entirely composed of small immature specimens. The fishery is an artisanal subsistance fishery, mainly carried out by fisherwomen as it is on Lake Paniai.

Common carp stocking in Lake Tigi

Common carp were introduced by airdrops during the 1930s. In 1964, 20 000 carp fingerlings were introduced from the Enarotali hatchery. Further batches of common carp fingerlings amounting to 200 000 have been put into the lake by the Waghete hatchery founded under the FAO 1972 project.

The persistent turbidity of the lake limits its productivity. According to a fisherwoman the prawn (Cherax sp.) fishery has deteriorated since the introduction of carp into the lake.

Common carp stocking in Anggi lakes

No endemic fish have been reported in Anggi lakes. The Government first introduced 10 000 common carp into Anggi Giji in 1973. This was followed by a further 10 000 carp of the Majalaya strain in 1984, with 3 000 *O. niloticus*. Lake Anggi Gita was stocked with 3 000 Majalaya carp in 1984. All the introductions came from the hatchery at Manokwari.

The daily catch from Lake Anggi Giji is estimated to be 40 kg/day, and it consists entirely of carp measuring 300 to 500 g, but with some specimens reaching 8 kg.

All the fish caught are consumed by the fisherman and his family, and nothing is marketed. Howard (1987) made a list of cyprinids which he considered suitable for stocking in the lakes of Irian Jaya (Table 9).

Table 9

Carp species recommended for stocking in the lakes of Irian Jaya

Carp species	Lake	Size (cm)	Comments
Common carp, Majalaya strain	Sentani	9 - 12	Herbivore/omnivore, tolerates low temperatures. Already established in highland lakes and rivers.
	Paniai	9 - 12	
	Tage	9 - 12	
	Tigi	9 - 12	
	Anggi	9 - 12	
Tawes (*Puntius gonionotus*)	Sentani	7 - 9	Herbivore. Tolerates temperatures down to 15°C
	Paniai	7 - 9	
	Tage	7 - 9	
	Tigi	7 - 9	
Nilem (*Osteochilus hasselti*)	Sentani	5 - 7	Herbivore. Tolerates temperatures down to 15°C
	Paniai	5 - 7	
	Tage	5 - 7	
	Tigi	5 - 7	
Grass carp (*Ctenopharyngodon idella*)	Sentani	7 - 9	Herbivore, also grazer. Will spawn at 17.5°C.
	Paniai	7 - 9	

To increase the yield of the highland fishery by a factor of 4 at an assumed 30% survival rate, a stocking rate of 1 000 fingerlings per 5 ha is recommended. For Lake Sentani, to increase its yield by 36%, a restocking rate of 500 per 5 ha is recommended, but this forecast has the unknown influence of the parasite *Lernaea* on survival of stocks. In introducing fish species into bodies of waters the quarantine procedures must be adhered to.

4.2 Experiments on common carp culture in floating nets in lakes

Natural lakes are found only in the islands outside Java such as in Sumatera, Sulawesi, Kalimantan, Nusu Tenggara and Irian Jaya. The Research Institute for Freshwater Fisheries conducted experiments on common carp culture in floating net enclosures in Lake Toba in North Sumatera and Lake Tonadano in Sulawesi using nets, each measuring 7 x 7 x 2 m (1.5 m water depth), fish stocking density 245 to 300 kg/net, pelleted feed containing 16 to 30% protein and culture period of 4 to 6 months. The fish harvest was 720 to 2 631 kg/net, with the higher yields obtained when feed with higher protein content was used. The feed conversion values ranged from 2.2 to 3.4 (Hardjamulia *et al.*, 1986). However, the common carp culture in floating enclosures in these lakes has not been adopted by fish farmers. This is probably due to certain socio-economical and technical factors which need further investigations.

In certain other lakes floating net or floating cage culture is practised by farmers, but not for common carp. For example, in Lake Sentani in Irian Jaya, 236 sub-littoral net enclosures were recorded (Howard, 1987). In Jambi in Sumatera 360 cages were recorded in 1980 where the most dominant culture species is the local kelemak (*Leptobarbus hoeveni*). In Central Kalimantan the number of floating cages grew from 1 065 in 1978 to 5 252 in 1980. In East Kalimantan the number of floating cages grew from 89 in 1978 to 1 965 in 1981 and the dominant culture species was snakehead (*Channa striatus*) (Hardjamulia *et al.*, 1986).

5. CONCLUSIONS

(i) Stocking and culture of cyprinids (carps) as well as other suitable fish species in reservoirs and lakes in Indonesia are recognized as one of the most important measures of fishery management of these waters to increase their fish yield or to improve the species composition of their fish population. In general, there is a good opportunity to increase the yield because the actual average catch from inland waters of Indonesia is around 19 kg/ha/yr which is much lower than their potential yield estimated to be around 57 kg/ha/yr, although certain smaller reservoirs in Java have been found to produce much higher catch such as Darma reservoir in West Java with 270 kg/ha/yr, Pacal reservoir with 380 kg/ha/yr, Selorejo reservoir with 250 kg/ha/yr, and Bending reservoir with 150 kg/ha/yr, all of them being located in East Java province. Larger areas of reservoirs and lakes are available for stocking and culture purpose. At least 14 reservoirs exist totalling 53 000 ha in surface area and more will be constructed. There are around 1 800 000 ha of lakes with at least 179 200 ha being considered to have good prospect for fisheries.

(ii) Records show that lakes were stocked with cyprinids already in 1905. Today, many lakes and reservoirs in Sumatera, Sulawesi, Maluku and Irian Jaya are being stocked. However, stocking of cyprinid and other fish is still irregular and limited relative to the large areas of water available. This is due to the insufficient supply of fingerlings. While specific data on stocking are available for some reservoirs and lakes, there are no such data for others and thus a quantitative assessment of the contribution of the stocked fish to the total yield is not possible.

(iii) Three cyprinid species have been used for stocking purpose, namely the common carp (*C. carpio*), tawes (*P. gonionotus*) and nilem (*O. hasselti*). Eight indigenous and exotic species of cyprinids have been found to be the dominant fish in the Juanda (Jatiluhur) and Saguling reservoirs in West Java and Wonogiri reservoir in East Java, constituting 81%, 84% and 58% of the fish catch, respectively. In the Juanda reservoir, *P. gonionotus* and *Hampala macrolepidota* are the first and second dominant species and form 47% and 30% of the catch. They are followed by non-cyprinids. In the Saguling reservoir the order of dominance is *H. macrolepidota* (30.5%), *O. hasselti* (26%), *C. carpio* (10.5%), *P. gonionotus* and *Mystacoleucus marginatus* (9% each), while the next cyprinid and non-cyprinid species are negligible. In the Wonogiri reservoir, the first in the order of species dominance is a non-cyprinid species (*Macrones* sp., 41%), followed by four cyprinid species namely *P. gonionotus* (24%), *H. macrolepidota* (17%), *Puntius bromoides* (10%), and *Dangila cuvieri* (6%). In Lake Tempe in Sulawesi *P. gonionotus* derived from stocking has been found to be the dominant species amounting to around 70% of the total catch. Common carp derived from stocking has been found to be the dominant species in certain highland lakes located over 1 700 m above sea level, namely in lakes Paniai (84%), Tage (100%) and Anggi (100%) while in Lake Tigi located 1 640 m above sea level stocked common carp was said to deteriorate the existing prawn (*Cherax* sp.) fishery.

(iv) Although it is biologically feasible to culture a number of cyprinids and other species in open waters, cyprinid (carp) culture as practised by farmers in reservoirs and lakes to date has been limited to culture in floating net in the Saguling and Cirata reservoirs in West Java. The common carp culture in floating net practised by farmers in these two reservoirs has been developing rapidly. In the Saguling reservoirs this common carp culture using a net enclosure of 7 x 7 x 2 m (1.5 m water depth), fish stocking density of 2.4 kg/m^3 of fish averaging 71.8 g fed three times daily with a commercial feed containing 24% protein at 3% of fish biomass per day, produced 1 070 kg (mean) ± 76 kg (S.E.) of fish per net in 90 days of culture giving a net profit of US $165 with a benefit to cost ratio of 1.44. There is a preliminary indication that the use of 9 x 9 x 2 m (1.5 m water depth) net enclosure and stocking density of only 0.5 kg/m^3 of fish averaging 63 g in weight may be more profitable giving a yield not significantly different from the former but giving a net profit of US $ 399 and benefit to cost ratio of 2.2. Certain limnological, socio-economical and technical factors exist in Saguling areas that support the rapid development of this type of common carp culture in this reservoir. In other reservoirs and lakes this type of common carp culture has not been developing.

(v) Much more research work on stocking of reservoirs and lakes as well as culture in these waters is still needed, especially on stocking.

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STATUS OF SCHIZOTHORAX SPECIES IN THE INDIAN-CHINESE SUB-CONTINENT

by

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1. INTRODUCTION

The sub-family Schizothoracinae (common name snow trout) of the family Cyprinidae is present in the Himalayan and sub-Himalayan region of the Indian-Chinese sub-continent. In Nepal, snow trout is called asla and is considered to be delicious to eat. Snow trout are present in cold watera from 1 380 m (Shrestha 1981) to 2 990 m (Terashima 1984). A maximum weight of 2.5 kg has been recorded from rivers Trisuli and Sunkoshi (Shrestha, N. and S. Shrestha, *pers.com.*). In India, this fish is distributed in the cold waters of Jammu and Kashmir (Sunder and Bhagat, 1979) and constitutes 10-20% in totsl commercial landings (Raina *et al.*, 1985). Some of the high altitude lakes in Nepal are inhabited only by *Schizothorax* spp (Ferro 1977; Pradhan 1982). Their population is decreasing sharply because of heavy pressure of fishing as they fetch a high price in the market and also due to natural calamities and human disturbances like construction of dams (Pradhan 1986; Pradhan and Swar, 1988) and roads.

2. GENUS SCHIZOTHORAX

Schizothorax generally prefer rapids and pools of big torrential atreams with temperatures ranging from 8 to 22°C. But some inhabit lakes without a connection to flowing rivers or streams (Pradhan, 1982). There are 28 species in the Himalayan and sub-Himalayan regions including Tibet, China and Pakistsn (Table 1). The body of snow trout is oblong and moderately compressed. It has two pairs of barbles and a membranous slit anterior to the anal fin which ia laterally bounded by a row of vertically placed scales repreaenting cave tiles (Rajbanshi, 1976). Mishra (1959) has classified snow trout into two genera: *Schizothorax* Heckel having suctorial lower lip, and *Schizothorax* Mishra with non-suctorial lower lip. *S.* Heckel includes *S. esocinus*, *S. niger*, *S. nasus*, *S. hergelii*, *S. macropogon*, *S. platifrons*, *S. pelzani*, *S. intermedius*, *S. argentatus*, *S. pseudaksaiensis* and *S. progastus*. In the streams of Himachal Pradesh in India it is found to occur at altitudes ranging from 1 180 to 3 000 m a.s.l. (Jhingran, 1982).

Table 1

List of *Schizothorsx* species in different countries

Species	Country
S. snnandalei	India, Nepal
S. argentatus	India
S. curvifrons	India
S. esocinus	India, Nepal
S. hergelii	India
S. hodgsonii	Nepal
S. intermedius	India
S. kozlovi	China
S. kumaonensis	India
S. labrusus	Chins
S. longipinners	India
S. luguherensis	China
S. macrophthalmus	Nepal
S. macropogon	India
S. microstomus	China
S. nepalensis	Nepal
S. nasus	India
S. niger	China
S. ninglangensis	China
S. pelzani	India
S. plagiostomus	India, Nepal
S. platifrons	India
S. progastus	India, Nepal
S. pseudaksaiensis	India
S. raraensis	Nepal
S. richardsonii	India, Nepal
S. skarduensis	Pakistan
S. taliensis	China

Schizothorax kumaonensis is a new species recorded by Menon in 1962 from Nainital, Uttar Pradesh, India. *S. esocinus* occurs in Kashmir and Ladakh, *S. progastus* in the headwaters of the river Ganga down to Sadiya in Uttar Pradesh (Jhingran, 1982). Three new species *S. raraensis*, *S. macrophthalmus* and *S. nepalensis* (Terashima, 1984) have been added to the list of *Schizothorax* species present in Nepalese waters. The other species are *S. richardsonii* and *S. plagiostomus*, *S. annandalei*, *S. esocinus*, *S. progastus* and *S. hodgsonii* (Gunther, 1861; Regan, 1970; Hora, 1923, 1937; Shaw and Shebbeare, 1937; Menon, 1962).

2.1 Feeding habits

Schizothorax richardsonii has been reported as herbivorous detritophagic bottom feeder (Sharma, 1984). Feeding intensity of *S. richardsonii* is higher during winter months than during the rainy season (Madhwal *et al.*, 1984). *S. nepalensis* has been reported as herbivorous whereas *S. raraensis* is insectivorous and *S. macrophthalmus* is planktivorous (Terashima, 1984). *S. esocinus*, *S. niger*, *S. macropogon*, *S. plagiostomus*, *S. curvifrons* and *S. longipinners* have been reported to feed essentially on diatoms, weeds and decayed organic matter. Sand is a common component of the gut content.

A study conducted with supplementary feed (egg yolk, buffalo liver, poultry feed, phytoplankton and insects) have shown 1.5 mm hatchlings of *S. plagiostomus* to grow to 32.6 mm in 240 days (Shrestha, *pers.comm.*).

The relative length of the gut of asla has been reported to vary depending on the fish species. The gut in *S. richardsonii* is very long and convoluted. A true stomach is absent but a well developed intestinal bulb is present to accommodate a good amount of plant food material (Sharma, 1984).

2.2 Reproduction and growth

Schizothorax richardsonii spawns during August-September in Garhwal, India (Sharma, 1984). These fish from Nepalese waters have been reported to bear spermatozoa in primary stage at all times and become prominent in November and April and exhibit no sexual dimorphism (Shrestha and Khanna, 1976). This fish has been reported to grow to 150-200 mm (100 g) in one year in cold water streams of mid hills. Masuda (1979) has reported that *S. plagiostomus* grow to 220 mm (226.2 g) in four years, whereas *S. progastus* grow to 257 mm (362.7 g) in the same period of time. Peak breeding season is in August-September and February-March. The numbers of eggs varied from 500 to 4 000 per female (Pradhan, *pers.comm.*).

Schizothorax esocinus were found to mature only in the third summer. The spawning period was from April to the end of June and the number of eggs ranged from 3 910 to 53 106. Eggs measured 3.6 mm in diameter. In the Dal Lake, Kashmir, India, these fish migrate towards cold water streams with a temperature range of 14-17°C when the water of Dal Lake warms up to 22-27°C. After spawning in cold water, they return to the lake leaving their spawn in the stream (Raina, 1977).

Sexual dimorphism is exhibited by *S. macrophthalmus*, *S. nepalensis* and *S. raraensis*. These fish spawn after mid May (Terashima, 1984). The seasonal cycle of *S. plagiostomus* can be divided into resting phase (June to May), immature phase (June to July), mature phase (July to August), first spawning phase (September to October), releasing phase (November), dormant phase (December to January), second spawning phase (February to March) and spent phase (April) as reported by Shrestha and Khanna (1976). But other workers have observed *S. plagiostomus* spawning during OctoberNovember and *S. progastus* spawning during March-April (Shrestha, *pers.comm.*). The hatching period of *S. curvifrons* at water temperature of 15-20°C varied from 108 to 120 hours or more. The eggs are laid in clean water with gravelly bottom at 30-60.cm depth (Jhingran, 1982). The length of larva at hatching time is 7 mm and it grows to 11 mm in 7 days. The body of the newly hatched larva is transparent without any pigmentation. Fry reach 18-20 mm in 45 days, develop scales and start feeding on zooplankton (Gupta and Subla, 1985). Fries of S. esocinus reared in well oxygenated waters (7.8 - 8.8 ppm dissolved oxygen) having a temperature range of $15-18^{\circ}C$ and with 250-500 stocking densities per $0.1\ m^2$ gave 47-55% survival (Raina *et al.*, 1985). The range of suitable water temperature for snow trout spawning has been reported to be $14-21^{\circ}C$ (Raina, 1977).

3. CONCLUSIONS

Schizothorax can be considered economically important fish in the Himalayan and sub-Himalayan regions as the number of fish species in these regions is limited. There is a heavy fishing pressure on this fish as people like its taste. At present, poor knowledge of the biology of these fish hinders the management of its fishery.

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KATLE (ACROSSOCHEILUS HEXAGONOLEPIS), A COLDWATER CYPRINID OF NEPAL

by

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1. INTRODUCTION

Nepal is a landlocked country having considerable water resources. It has nearly 6 000 rivers and streams totalling about 21 000 km in length, about 5 000 ha of natural lakes, and 1 500 ha of multipurpose reservoirs. 171 fish species have been listed in Nepal by Rajbanshi (1982). Among the many economically important local fish species belonging to the coldwater cyprinids, asla, katle and mahaseer are liked by most people. These fish are presently being studied in a number of Government fish centres which concentrate especially on the growth, reproduction and migration habits.

Katle is a favourite sporting fish of hill streams and occurs in Assam, Bengal, Burma and Nepal (Jhingran, 1982). Katle is abundant in most of the big rivers, lakes and reservoirs of Nepal between 250 and 1 500 m above sea level. This fish has upward and downward migration and local fishermen use to catch the maximum of fish during the migration season. Katle migrates upstream in May/June and downstream in September/October. Katle is an omnivore (Ferro and Badagami, 1980). Jhingran (1982) reported that the fish feeds mainly on insect larvae, aquatic beetles and flies. He also mentioned that aquatic vegetation and marginal grass constitute a major food item found in the gut of advanced fingerlings and adults. Small fingerlings have a bottom feeding habit. The fish stocks have been decreasing due to overfishing and the use of illegal fishing methods such as poisoning and dynamiting. Natural calamities such as floods and landslides have also had a negative impact on katle. Therefore, fingerling production by artificial breeding and their release in rivers, lakes and reservoirs is considered to be among the best approaches on how to rehabilitate the fish stocks.

2. COLOUR, SIZE AND MORPHOLOGY

Acrossocheilus hexagonolepis is similar to mahaseer (Tor tor) from which it differs in head length and presence of a lateral golden band (Shrestha, 1981). The colour is deep copper. Shaw and Shebbeare (1937) distinguished these fish species on the basis of colouration: Tor putitora has darker and deeper colours without pores below the eye and Tor tor has olive green on the back and top of the head. Acrossocheilus hexagonolepis is silvery and slender. Jhingran (1982) calls katle as copper or chocolate mahaseer. Hexagonolepis denotes the hexagonal shape of the exposed portion of a scale.

[1/] Author's comments on the edited manuscript were not received in time for printing. The Editor therefore took the liberty of adjusting the text according to his best understanding of the original.

The fish is dark grey on the dorsal side, silvery on the abdomen, and has large and regular scales (Fig. 1). Body is oblong, compressed, snout obtusely rounded with large mouth. Caudal fin is deeply forked. Lateral line scales number 28-31. The average size is 600-800 g, maximum size of 2 900 g was recorded in Kulekhani reservoir. Ferro and Badagami (1980) mentioned the largest size for male as 27 cm and 29 cm for female.

3. MATURITY AND BREEDING SEASON

The maturity is reached after 3 years and the fish mature earlier than mahaseer. Males are generally smaller than females. Ferro and Badagami (1980) reported that the maturity is attained at 11 cm (male) and 16.5 cm (female). Katle tolerates a wide range of temperature (15-30°C) and matures in the third year (Rajbanshi, 1982). The breeding season in Nepal is August-September and the species breeds naturally on stones and gravel at water temperatures of 18-23°C. Akmed (1948) reported that katle breeds from April to October with interruption, the peak period being August and September. Jhingran (1982) reported breeding from May/June to August/ September, and Rai (1978) in August-September.

4. AQUACULTURE EXPERIENCE

Katle has been studied in the Trisuli Fisheries Centre where for the first time an artificial breeding was succesafully tried out in 1977. For brood fish, young fish were collected from Trisuli river (500 m a.s.l.) and cultured in earthen ponds. Some brood stock was collected directly from the river. Fish were caught using cast and gill nets. Earthen ponds had a constant water temperature of 15-22°C. The brood fish were fed on a mixture of maize flour, wheat flour and oil cake. Brood fish ready to spawn developed rough and small prickles on the operculum. This character developed more in males than in females. The colour changed from faint grey to brown.

In August, brood fish ready to spawn were stripped without using hormone injection. The stripped eggs were collected in a dry plastic bowl and mixed with milt and stirred thoroughly softly with feather. The stripped eggs were sticky and adhered together but could be separated with the feather. The fertilized eggs were washed many times with clean water.

Fertilized eggs were transferred into hatching trays for incubation and a constant water flow was maintained. The flow of water (from Trisuli power station reservoir) for incubation was 8.6 l/minute. The newly hatched larvae of 6.5 mm length were kept in the same hatching tray for five days.

The physico-chemical characteristics of water during incubation were as follows: temperature 18-23°C; dissolved oxygen 9-11 ppm; pH 7.7; and water transparency 7.9-12.5 cm. Dead eggs were removed by hand picking and the number of eggs was recorded.

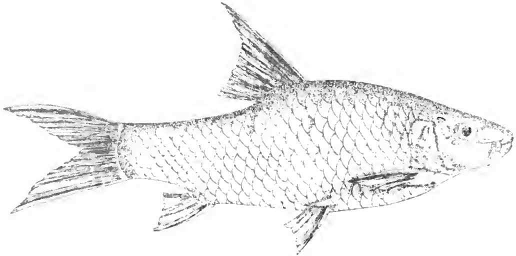

Fig. 1. Katle (Acrossocheilus hexagonolepis)

After 6 days the hatchlings (9.7 mm) were transferred into a rearing happa which was set inside the cement cistern. Ten days old hatchlings 10.1 mm long were fed four times a day supplementary feed which was one boiled egg and 20 g of buffalo liver mashed together through a fine wire mesh. In happa the physico-chemical properties of water were as follows: Temperature 20–23°C; dissolved oxygen 6.9 ppm; pH 6.7, and water transparency 100 cm. 2 526 eggs from the pond female brood fish and 3 461 eggs from the reservoir female brood fish were obtained (Table 1).

Table 1

Eggs from brood fish raised in two different environments

	Reservoir brood		Pond brood	
	Female	Male	Female	Male
Total length (cm)	36.5	32	28	25.5
Weight (g)	600	300	264	160
Girth (cm)	6.5	6	6.5	4.5
Weight of eggs (g)	30	–	24	–
Number of eggs	3 461	–	2 526	–

The size of stripped eggs was 2.1–2.2 mm. The eggs were whitish from reservoir brood fish whereas the eggs were yellow from pond brood fish. The eggs were heavier than fresh water. According to Jhingran (1982) eggs are transparent and yellowish, spherical, 2.3–2.5 mm in diameter. The yolk is devoid of oil granules. The fertilization rate was about 99% (Rai, 1978). The fertilized eggs swell and develop through different stages after incubation.

The hatching percentage was over 75%. The new larva was 6.5 mm long and transparent. Hatchlings consumed yolk sac completely after 10 days when reaching 10.1 mm, at which size they began to feed on supplementary feed. Hatchlings did not have air bladder but pigment appeared after 3 days of hatching. The hatchlings came up to the surface and then sank down to the bottom. After the fifth day they crowded at the corner of the rearing happa. After 10 days the hatchlings (10.1 mm) began to swim near the surface of the water.

Katle has sticky eggs which are attached to grasses or rocks. Food given to brood fish seems to determine the egg colouration. The high fecundity suggests that there is a potential for a large-scale fingerlings production in earthern ponds. Katle is appreciated as table fish and this further speaks for the development of pond culture for this species. Jhingran (1982) pointed out that katle is suitable for pond culture in Tamil Nadu where the growth was about 23 cm in the first year.

50 g size fingerlings of katle, tagged on pectoral fin, were released into Trisuli river, and some fingerlings of the same size were stocked in an earthen pond to compare the growth rate in two different environments. Fish reached 100 g in the earthen pond, but 200 g in the river. This showed that katle grow better in the natural river environment than in earthen ponds. However, the food habit, growth, temperature tolerance and fecundity show the feasibility of pond culture and the possibility of producing a larger number of fingerlings for their release in natural water bodies.

5. CONCLUSION

Katle, *Acrossocheilus hexagonolepis*, is a tasty native sport fish. The first artificial breeding was carried out successfully in 1977 at Trisuli Fisheries Development Centre, Nuwakot, and resulted in a high fertility rate. The average size of the fish is 600-800 g and it is present in most of the major rivers, lakes and reservoirs of Nepal, in the hilly region at an altitude from 250 to 1 500 m above sea level. The potential of this fish from pond culture is highlighted.

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A REVIEW OF THE UTILIZATION OF CARPS IN INLAND FISHERIES MANAGEMENT IN THE PHILIPPINES

by

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1. INTRODUCTION

In the Philippines, carps have not been extensively used in the management of the fisheries resource of inland water bodies. While the culture of milkfish in fishpens and tilapia in fish cages has been well-established, the carp industry is still in its infancy despite the fact that the country has important endemic carp species in some major lakes and that bighead carp was introduced some 20 years ago. There are indications, however, that the next few years may see the expansion of the carp industry as a result of its growing market acceptability, the availability of technology on its artificial/induced spawning, and its successful culture in fishpens in Laguna de Bay.

This paper presents a brief review of the present status of carp utilization in inland fisheries management in the Philippines and ventures a guess as to its future in the country.

2. CARP SPECIES AND YIELDS

Philippine lakes and reservoirs are generally characterized by a low diversity of indigenous fish which have been supplemented by the introduction of exotic species mainly milkfish, tilapia and carp (Table 1).

2.1 Endemic species

It is only in Lake Lanao where endemic cyprinids exist. This deep, oligotrophic lake, the Philippines' second largest at 34 000 ha, has a native flock of cyprinids consisting of 20 species of the genus *Puntius* (also referred to as *Barbodes* or *Barbus*) and several derived genera - *Mandibularca*, *Spratellicypris*, *Cephalocampus* and *Ospatulus* (Table 2) (Frey, 1969). Myers (1960) theorized that the evolution of these cyprinids from a single progenitor, *Puntius binotatus*, must have been made possible by their geographical isolation and the absence of biological competitors/predators there. It has been suggested that in nearby Lake Mainit, *Puntius binotatus* did not diversify into several species because of the periodic occurrence of salinities which it could not tolerate, or because competing euryhaline ichthyofauna could have made rapid speciation impossible (Lewis, 1973).

In Lake Lanao, endemic cyprinids comprised about 50% of the total catch in 1963 to 1964. The accidental introduction of two species of goby (*Glossogobius giurus* and *Hypsilotrix agilis*) in the early sixties had caused a dramatic decline in catch of these endemics in recent years. From 50% in 1963-64, the percentage contribution of the endemic cyprinids declined to 28% in 1979, alongside with the increase in percentage of gobies to 29% (Table 3) (Baluyut, 1983). The displacement of the native cyprinids by the introduced species - mainly gobies and tilapia - seems to have become irreversible, with the situation in the past three years being the exact opposite of that in the early sixties.

Table 1. Fish species found in some major Philippine lakes.

Fish species (scientific name)	Common name	Laguna de Bay c/	Laguna Naujan d/	Lake Buluan e/	Lake Mainit f/	Lake Lanao g/
Anabas testudineus a/	climbing perch	+		+	+	+
Anguilla sp. b/	eel	+	+	+	+	+
Arius manilensis	sea catfish	+				
Atherina sp.	silverside				+	
Barbodes binotatus	common barb			+	+	
Caranx sp.	caranx	+	+		+	
Chanos chanos a/	milkfish	+	+		+	+
Chronophorus melanocephalus	rock goby	+				
Clarias sp.	catfish	+	+	+	+	+
Cyprinus carpio a/	common carp	+				+
Hemiramphus sp.	halfbreak	+				
Glossogobius biocellatus	sleeping goby	+				
Glossogobius giurus	white goby	+	+	+	+	+
Megalops cyprinoides b/	tarpon	+	+			
Microgobius lacustris	goby	+				
Mugil sp. b/	mullet	+	+		+	
Ophicephalus striatus	catfish	+	+	+	+	+
Ophiocara aporos	sleeper	+	+		+	
Puntius javanicus a/	tawes	+				
Scatophagus argus a/	spadefish	+	+		+	
Tawnioides sp.	eel goby	+	+			
Therapon plumbeus	therapon	+				
Tilapia spp. a/	tilapia	+				+
Trichogaster pectoralis a/	snakehead gouramy	+				+
Trichogaster trichopterus a/	three-spot gouramy	+				

a/ Introduced species

b/ Migratory species

c/ Laguna Lake Development Authority, 1978

d/ Gracia, n.d.

e/ Yap, Ferriols and Baluyut, 1983

f/ Lewis, 1973

g/ Villaluz, 1966

Table 2. Cyprinid fish species endemic to Lake Lanao (Villaluz, 1966).

Scientific Name	Local Name
Puntius tamarus Herre *a/*	pait
P. baolan Herre	baolan
P. binotatas Herre	pait
P. clemensi Herre	bagangan
P. dize Herre	disa
P. flavifuscas Herre	tumba
P. katolo Herre	katolo
P. lanaoensis Herre	kundur
P. lindog Herre	lindog
P. manalak Herre	manalak
P. sirang Herra	sirang
P. tras Herre	tras
P. tumba Herra	tumba
Cephalocampus pachychilus Herre	bitungu
Mandibularca resinus Herre	bagangan sa erungan
Ospatulus truncatulus Herre	bitungu
O. palaeaophagas Herre	bitungu
Sprattellicypris palata Herre	palata

a/ Also referred to as *Barbodes* or *Barbus*.

Table 3. Percentage composition of fish sold in the Marawi City Market, 1963-1979 (Mindanao State University College of Fisheries, 1980, unpublished).

	1963-1964	1974	1975	1976-1977	1979
Cyprinids	49	49	57	57	28
Common carp	12	1	-	1	-
Mudfish	12	11	11	14	26
Goby	6	14	10	11	8
Tilapia	6	9	5	9	3
Shrimps	3	8	8	5	11
Snails	10	6	7	3	3
"Bagong Lipunan" (goby) a/	-	-	-	-	21 b/
Total Catch (in '000 kg)	1,986	872	1,236	715	169

a/ *Hypsilotrix agilis*

b/ Does not include catch dried and sold for fish meal preparation.

As can be seen in Table 4, catches of the carps and other cyprinids have continued to decline, reaching 45 t in 1987. In contrast, the combined contribution of gobies and tilapia to total fish production of Lake Lanao has risen to 4 696 t or 63.6% in 1987.

2.2 Exotic species

Common carp (Cyprinus carpio), rohu (Labeo rohita), and bighead carp (Aristichthys nobilis) are the main species used for stocking and culture purposes in the Philippines. Silver carp (Hypophthalmichthys molitrix) and grass carp (Ctenopharyngodon idella) have been brought into the country and have been used for stocking the major reservoirs. As shown in Table 5, common carp is found in all the major Philippine lakes while rohu, bighead, silver, and grass carp have been introduced in the major reservoirs where they occasionally appear in the catches. This is because only common carp is known to breed naturally in these waters (Guerrero, 1988). The other species have to be artificially bred and stocking efforts need to be sustained if populations of the fish are to be established.

Average yields from the various exotic carps in these lakes ranged from 80 t/yr in the 8 000 ha Naujan Lake to 4 056 t/yr in Laguna de Bay, the country's largest lake at 90 000 ha, for the three-year period 1985-1987 (Table 6). The average contribution of carp to total production from capture ranged from a low 1.5% in Lanao Lake to a high 32% in Lake Buluan. The percentage contribution of exotic carps to total fish landings in Lake Lanao could actually be lower than the estimated 1.5% considering that the 140 t average annual catch includes the endemic cyprinids as the Bureau of Fisheries and Aquatic Resources (BFAR) does not differentiate among carp species.

The carp production figures reflected in Table 6 acquire new meaning when viewed within the context of total national production from inland capture fisheries. As shown in Table 6, the total carp landings from open water capture fisheries was 2.7% of the 219 590 t of fish landed from seven major lakes and 2.4% of total national inland water fish capture in 1987. These lakes constitute 92% of the total freshwater resource of the Philippines and contributed 86.4% to the total inland municipal catch of 254 025 t in 1987. This latter figure, however, represents only 11.8% of the total fish production of 2.14 million tons in 1987 (Table 7),in the light of which, the 6 000 t total open water carp yield in 1987 translates into an insignificant 0.28% of overall fish production in the Philippines.

While the abovementioned carp yield does not reflect production from aquaculture, and could therefore be higher than the cited figure, yield from pen and cage culture has not been substantial as to significantly increase the contribution of carps to the total fisheries production of the country.

Table 4. Fish catch (t) and composition, Lake Lanao, 1985-1987 (BFAR Statistics).

Species	1985		1986		1987	
	Catch	% of Total	Catch	% of Total	Catch	% of Total
Finfish						
Carp/cyprinids	249	2.5	127	1.3	45	0.6
Tilapia	682	7.0	2,415	24.2	2,778	37.6
Gobies	1,768	18.1	5,376	53.9	1,918	26.0
Other species	1,098	11.2	1,062	10.6	1,307	17.7
Sub-Total	3,797	38.8	8,980	90.0	6,048	81.9
Crustaceans	5,993	61.2	1,002	10.0	1,334	18.1
TOTAL	9,790	100.0	9,982	100.0	7,382	100.0

Table 5. Occurrence of exotic carp species in major Philippine lakes and reservoirs.

Lake/Reservoir	Common Carp	Rohu	Bighead Carp	Silver Carp	Grass Carp
Laguna de Bay	+	+	+		
Lanao	+				
Taal	+				
Naujan	+				
Buluan	+	+			
Bato	+				
Pantabangan	+	+	+	+	+
Magat	+				
Angat	+	+	+	+	+

Table 6. Carp yields (t) from open water capture fisheries in major Philippine lakes (1985 1987 BFAR Statistics).

Lake	Area (ha)	1985			1986			1987			Average, 1985 1987		
		Total Catch	Carp Landings	% of Total	Total Catch	Carp Landings	% of Total	Total Catch	Carp Landings	% of Total	Total Catch	Carp Landings	% of Total
Laguna de Bay	90,000	198,291	3,101	1.6	200,269	5,652	2.8	189,679	3,399	1.8	176,080	4,050	2.0
Lanao	34,000	9,790	249	2.5	9,982	127	1.3	7,382	45	0.7	9,051	140	1.5
Taal	33,400	13,632	278	2.0	11,967	304	2.5	14,705	444	3.0	13,434	342	2.3
Naujan	8,000	670	63	9.4	707	83	11.7	792	94	11.8	723	80	11.0
Mainit	7,340	1,471	162	11.0	1,309	177	13.5	1,440	198	13.8	1,406	179	12.7
Buluan	6,500	865	322	37.2	2,218	380	17.1	4,157	1,622	39.0	2,413	774	32.0
Bato	3,800	1,391	133	9.6	1,610	155	9.6	1,435	204	14.2	1,478	164	11.1
TOTAL	183,040	226,110	4,308	1.9	228,062	6,878	3.0	219,590	6,006	2.7	224,585	5,729	2.5

Table -. Production from the different fisheries sectors of the Philippines, 1987, (BFAR, 1988).

Sector	Production volume (t)	Percentage to Total
Commercial Fisheries	585,636	27.4
Municipal Fisheries*		
Marine	8[illegible],947	37.5
Inland	254,025	11.8
Aquaculture		
Inland	278,087	13.0
Marine	220,5[illegible]	10.3
TOTAL	2,141,197	100.0

* Refers to fishing done in coastal and inland waters with or without boats of 3 gross tons.

3. CARP HATCHERY AND CULTURE

3.1 Historical overview and present status

The common carp (Cyprinus carpio) was introduced from Hong Kong into the Philippines in 1915, successfully bred, and stocked by the BFAR in the inland waters where it became established (Guerrero, 1988). Carp culture in the country started in 1966 when fingerlings of bighead, silver, grass and common carp were grown in ponds at the BFAR Experimental Station in Tanay, Rizal (Chaudhuri, 1979 as cited in Fermin, 1987). Carp polyculture experiments in ponds and rice paddies were subsequently undertaken at the Freshwater Aquaculture Center of the Central Luzon State University (CLSU) in Munoz, Nueva Ecija (Guerrero, 1988).

In 1970, the artificial propagation of carps, particularly common carp, by hormone injection, was first demonstrated by fishery biologists from BFAR and the FAO Freedom from Hunger Campaign working with two private hatcheries in Candaba, Pampanga and Dingle, Iloilo (Camacho and Lagua, 1987). In the mid-1970s, two enterprising private fish culturists ventured into hatchery of Chinese carps and experimented with pen culture of carps in Laguna de Bay (Fermin, 1987). By 1982, both businessmen were culturing bighead carp in the lake, virtually monopolizing the business (Almazora, 1987).

In 1981, the SEAFDEC Freshwater Research Station in Binangonan, Rizal began research on the induced spawning of bighead carp following the return of technical personnel from training in India and the People's Republic of China, and the importation of bighead carp fingerlings from China. The rearing of bighead and common carp in polyculture with milkfish in pens and with tilapia in cages was likewise undertaken and demonstrated to be technically and economically feasible. From 1980 to 1984, the SEAFDEC Binangonan Station concentrated its efforts on the artificial propagation of bighead and silver carp using techniques employed in China. Following the successful gonadal maturation and rematuration of bighead and silver carps in floating cages throughout the year, and the induced spawning of lake-reared carps in 1983, fingerlings were made available to private fishpen and cage operators for growing to marketable size in pens and cages in Laguna de Bay (Fermin, 1987). By 1984, SEAFDEC was consistently producing carp fingerlings and actively disseminating the technology of artificial spawning of carp to the private sector. However, since it takes two years for bighead carp to mature under Laguna Lake conditions, it was only in 1986 that most of the new private hatcheries began to operate and fingerlings became readily available (Almazora, 1987).

In March 1986, some 17 hatcheries were identified in various locations around Laguna de Bay, of which 14 were privately owned and three were government operated. The largest, the Puzon hatchery in Santa Maria, Laguna, consists of 16 ha, of which 14 ha are nursery ponds. It has been in operation since the late 1970s. The second largest hatchery, a 4 ha complex, is operated by the Frabelle Fishing Corporation, also in Santa Maria, Laguna (Almazora, 1987).

To date, about half of the hatcheries reportedly under construction and operation in 1986, have either stopped operations or have remained unoperational. The Frabelle Hatchery has closed down because the owner did not find the venture economically profitable as compared to his other business interests (Baldia, 1988, pers.comm.). The Government hatcheries are not operational either. Even the SEAFDEC Binangonan Station has substantially reduced its production in line with its shift in research focus. It was felt that SEAFDEC, as a research institution, has already adapted the technology and transferred it to the private sector for use in commercial production.

No official statistics are available, however, on the quantity of carp fingerlings produced by these hatcheries. Almazora (1987) estimated fingerling production from existing hatcheries to be about 4.25 million in 1986. He noted that existing fingerling supply is difficult to quantify accurately based on the production capabilities of the hatcheries alone, since production level is a function not only of the physical infrastructure but also of the availability of mature broodstock and technical competence of the operator or his staff. For example, one backyard operator produced 1.5 million fingerlings in only six months of operation while a large hatchery complex was able to produce only 500 000 in that same period.

In contrast, grow-out operations have been expanding lately, mainly as a result of the shift in fishpen culture species from milkfish to bighead carp. This shift was triggered by the observed poor growth performance of milkfish in pens in Laguna de Bay since 1984, on the one hand, and the satisfactory growth of carp, on the other. While milkfish used to reach a marketable size of 150 to 200 g (or 5-7 fish/kg) in five to six months in the early years of the fishpen industry, the rearing period had to be extended to over a year, harvest sizes dropped to 12 fish or more per kilo, and recovery rates were dismally low at 10-20% (from traditional 50-60%). By comparison, bighead carp can be harvested after six months when the fish reach sizes of 1-2 kg each.

In 1986, some grow-out operators engaged in bighead carp culture in fishpens and/or cages in an area of approximately 1 900 ha, mostly in the Rizal side of Laguna de Bay (Almazora, 1987). While exact figures are not available on the fishpen hectarages devoted to bighead carp culture, it is highly probable that the area has grown in the past two years as a result of the observed shift of more fishpen operators to carp, not only because of its good culture performance but also because of its improved consumer acceptability and therefore better marketability and increased profitability (Crisanto, pers.comm.).

Based on an average yield of 6 t/ha/crop (assuming a stocking density of 5 000 fingerlings/ha, a recovery rate of 60% and a harvest size of 2 kg/fish), production from the estimated 1 900 ha of fishpens devoted to bighead carp must have been at least 11 400 t in 1987 (assuming only one crop) or roughly 40% of the approximately 31 000 t reported production from fishpens/cages in Laguna de Bay in that year.

3.2 Industry practices

3.2.1 Broodstock development and management

In the Philippines, bighead carp is the most popular species for culture although common carp is also used on a limited scale. For both species, broodstock development is widely practised.

Carp broodstock is raised from fingerlings in either cages, fishpens, or earthen ponds. While the investment and maintenance costs are lower in fish cages, operators prefer to use earthen ponds to eliminate or reduce the risk of losing the entire stock if the cages are damaged by typhoons or vandalized by poachers.

The broodfish are sampled monthly to assess their growth and gonadal development. Under Laguna Lake conditions, bighead and silver carps attain sexual maturity in 2 to 2.5 years, each ranging from 3-4 kg. As they undergo spontaneous gonadal maturation and rematuration throughout the year without hormonal inducements, the females can be used repeatedly for several years until fecundity drops. Broodstock maturation rates peak in summer (March to May) when natural food is abundant, and decline gradually with the approach of the cold season (December to January) (Fermin, 1987).

3.2.2 Breeding and seed production

Gravid females are conditioned together with sexually mature males in concrete or galvanized iron cylindrical tanks for 18-24 h prior to hormone injections. The female is then taken out of the tank and stripped of its eggs which are collected in an enameled basin. A 3 kg breeder can spawn 15 000 to 200 000 eggs.

Simultaneously, two or three males are stripped of milt directly into the eggs and stirred with a fowl feather. Fertilization rates vary from 23-88%; incubation ranges from 13-18 h at water temperatures of 28-30°C; and hatching rates vary from 7-36% (Fermin, ibid.).

Funnel-shaped hatching or incubation tanks are most popular in the Philippines. These tanks can be made of glass, plastic, fibreglass, or galvanized iron, with water capacities ranging from 5 to 1 000 l, depending on the number of eggs to be hatched. Typical stocking densities for hatching tanks are 500-1 000 hatchlings/litre (Almazora, 1987).

3.2.3 Larval rearing

Three to five days from hatching, the larvae are transferred to concrete or fibreglass larval rearing tanks or to bolting cloth cages placed in ponds. Stocking rates vary from 30 000 to 50 000 larvae/m^3 (Almazora, ibid.).

3.2.4 Nursery and grow-out operation

After one week in larval rearing tanks or cages, the fry are transferred to nursery ponds or hapa cages. The fry are reared to fingerling size of 1-3 g each for approximately 2-4 weeks. Typical stocking density is 350-500 fry/m², later thinned out to 100-300 fingerlings/m². In Laguna de Bay, stocking density can be increased to 1 000-1 500 fry/m².

Carp fingerlings are then transferred to the grow-out pen or cage and grown either in monoculture or in polyculture with milkfish or tilapia. Stocking density varies among operators but typically ranges from 5 000-10 000 fingerlings/ha. Rearing period varies from 6 to 8 months when the fish reach sizes of 1-2 kg.

3.3 Economics and marketing

A study on the production economics of bighead carp culture vis-a-vis that of milkfish and tilapia has shown that bighead carp is four times more profitable than milkfish and six times more profitable than tilapia. Although cost of carp fingerlings at 2 pesos per fingerling is higher than that of milkfish (0.35 peso/fingerling) and tilapia (0.20 peso/fingerling) and the ex-farm price of bighead carp is lower than milkfish and tilapia at 10-12 pesos/kg (compared to 20 pesos/kg of milkfish and tilapia) its fast growth rate and high survival rate more than compensate for these drawbacks (Almazora, 1987).

The profitability picture should be much better at present with higher selling prices of 22 pesos/kg, ex-farm, and 25 pesos/kg at the wholesale markets. The higher market prices are indicative of a much improved consumer acceptability and the wider use of the fish in the food industry - mainly as a food extender and as a substitute for expensive fish fillets.

4. CONCLUSIONS

With the successful adoption of the Chinese technology on carp seed production and the demonstrated viability of carp culture in fishpens and fish cages in Laguna de Bay, the only other constraint to the rapid expansion of the use of carp, mostly bighead, as a major culture species in Philippine lakes and reservoirs is its selective consumer preference and therefore limited marketability.

The limited market acceptability has been attributed to two major objections to the fish: namely, it has too many bones and it does not taste good (Guerrero, 1988). While there may be some basis for these observations, it is felt that with efforts directed at information dissemination and marketing campaigns (including cooking demonstrations), bighead carp may eventually become an important food fish in the country in much the same manner that the perception for tilapia has changed from that of a trash fish to that of a highly desirable commodity.

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THE USE OF COMMON CARP AND ASIAN CARPS IN THE MANAGEMENT OF LARGER INLAND WATER BODIES IN SRI LANKA

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1. INTRODUCTION

Several species of exotic carps have been introduced into the reservoirs of Sri Lanka. Their contribution to the commercial fish catch, which is dominated by tilapia (Oreochromis mossambicus), is insignificant in many reservoirs. In some of the hill country reservoirs, common carp production is high. Among the recently introduced Chinese and Indian major carps, Labeo rohita has been the most successful species appearing in the commercial catches of some perennial reservoirs.

The impact of stocking of carps in reservoirs has been subject to criticism mainly due to low recovery rate and failure of these species to contribute significantly to the commercial fish catches. The economic feasibility of stocking of carps in large perennial reservoirs has not been proved so far.

However, certain factors such as size of carp fingerlings, stocking rate, fishing methods and presence of obstacles in the reservoirs could affect the carp production. Pawaputanon (1986) reported an improved recovery rate of 20% in one year when the tagged larger sized fingerlings of L. rohita were stocked in Ubolratana reservoir in Thailand.

Among the indigenous cyprinids only Labeo dussumieri and Puntius sarana are of commercial importance. It has been pointed out by De Silva and Sirisena (1987) that a subsidiary gill net fishery could be established to exploit minor cyprinid resources in the reservoirs.

In this paper an attempt is made to evaluate the contribution of indigenous and exotic carp species to the fish production in larger perennial reservoirs in Sri Lanka.

2. INTRODUCTION OF EXOTIC CARPS

There are about 59 species of fish found in the fresh waters of Sri Lanka (Fernando and Indrasena, 1969; Fernando, 1973). At least 20 of the freshwater fish species are valued as food fish (Indrasena, 1965; Fernando and Indrasena, 1969; TAMS, 1980). Since the introduction of Salmo trutta in 1882, eighteen exotic species have been introduced into the country (De Silva, 1983; Chandrasoma, 1983). However, only thirteen species have been established either as naturally breeding populations or economically important species.
These are Cyprinus carpio, Carassius carassius, Oreochromis mossambicus, Osphronemus gouramy, Ctenopharyngodon idella, Aristichthys nobilis, Hypophthalmichthys molitrix, Catla catla, Labeo rohita, Cirrhinus mrigala and Salmo

gairdneri. Although records indicate that one Indian major carp (*C. catla*) and two Chinese carps (*C. idella* and *H. molitrix*) were introduced in 1942 and 1948 respectively, no attempts have been made to breed them artificially. These species were reintroduced by the Ministry of Fisheries in 1975, 1981 and 1982 respectively from China and India and they were successfully induced bred at the government hatcheries.

3. STOCKING OF CARPS AND THEIR CONTRIBUTION TO THE COMMERCIAL FISH CATCH

Stocking of common carp in reservoirs has been done for many years. Next to tilapia, common carp has been the major species produced in the fish breeding stations. Several millions of fingerlings have been stocked in the reservoirs, but the contribution of this species to the commercial fish catch is very low and often insignificant.

However, in Iranamadu tank (2 396 ha) this species contributes 10 to 20% of the total catch. Common carp has been stocked there since 1976. In some of the hill country reservoirs the contribution of this species is nearly 3% of the total catch, e.g. Castlereigh. It is assumed that common carp breeds and survives at a higher rate in these reservoirs.

Chinese carps have been stocked in some reservoirs since 1978. Udawalawe reservoir (3 374 ha), which is located near the main Chinese carp breeding station, has been stocked with grass carp and bighead carp since 1978. A total of 54 000 grass carp, 7 300 bighead carp and 13 400 silver carp fingerlings had also been stocked during 1978 to 1986. The reservoir was also stocked with 1 570 000 grass carp and 2 968 000 bighead carp post larvae in 1986. Stocking of Indian carps commenced in 1983. 252 680 rohu, 8 400 catla and 51 450 mrigal fingerlings were stocked during 1983 to 1986. 46 000 rohu, 65 750 catla and 51 450 mrigal post larvae were released into the reservoir in 1986. Indian and Chinese carps have appeared in the commercial catches since 1985. The percentage catch of Indian and Chinese carps were 6.59 and 0.32 respectively in 1985 and 1986 which was insignificant when compared to the number of fingerlings stocked. The major species caught was tilapia (68%). However, when the sluice gate was opened for irrigation purposes, large size carp were caught three years after stocking. Some of the bighead carp weighed as much as 13 kg. The performance of Chinese carps in other larger reservoirs has been unsatisfactory (Table 1).

Table 1

Contribution of different species to the total catch
(years in brackets)

Species	Stocking (number of fingerlings)	Production (t)	Total (t)	Percentage
Udawalawe (3374 ha)				
O. mossambicus	240 260 (78/86)	341 (85/86)	532.1 (85/86)	6 409
O. niloticus	-	26.1 (85/86)	532.1 (85/86)	4.9
O. melanopleura	-	44.5 (85/86)	532.1 (85/86)	8.35
C. carpio	-	-	-	-
C. idella	54 000(78/79)) 157 000 PL(86)))	1.7 (85/86)	532.1) (85/86)	0.32
A. nobilis	147 300(78,84,85)) 2 968 000 PL(86))	))		
H. molitrix	13 400 (84-86)	-	-	-
C. catla	8 400 (83/84) 65 750 fry (86)	-	-	-
L. rohita	252 680) (83/86))	35.07 (85/86)	532.1 (85/86)	6.59
C. mrigala	51 450 (84/86)) 23 400 fry (86))			
L. dussumieri	320 400 (83/85)	19.6 (85/86)	532.1 (85/86)	3.69
C. chanos	2 000 (80)	-	-	-
E. suratensis	-	38.5 (85/86)	532.1 (85/86)	7.23

Species	Stocking (number of fingerlings)	Production (t)	Total (t)	Percentage
P. sarana	-	-	-	-
T. khudree	-	-	-	-
Others	- (85/86)	25.6 (85/86)	532.1	4.8
Bathalagoda (262 ha)				
O. mossambicus	28 500 (82,83,85)	100 (83/86)	216.747 (83/86)	46.09
O. niloticus	10 000 (80,81,85)	64.6 (83/86)	216.74 (83/86)	29.8
O. melanopleura	-	-	-	-
C. carpio	3 100 (85/86)	-	-	-
C. idella	1 200 (85)	0.3 (85/86)	-	-
A. nobilis	1 700 (85/86)	0.1 (85/86)	99.5 (85/86)	-
H. molitrix	2 750 (85/86)	-	-	-
C. catla	-	-	-	-
L. rohita	19 300 (83,85,86)	9.6 (83/86)	99.5 (83/86)	9.6
C. mrigala	7 150 (85/86)	3.2 (85/86)	99.5 (85/86)	3.2
L. dussumieri	6 050 (79,81,86)	37.4 (83/86)	216.74 (83/86)	17.2
C. chanos	-	-	-	-
E. suratensis	-	-	-	-
P. sarana	-	-	-	-
T. khudree	-	-	-	-
Others	-	-	-	-

Species	Stocking (number of fingerlings)	Production (t)	Total (t)	Percentage
Dewahuwa (394 ha)				
O. mossambicus	-	23.54 (86)	29.7 (86)	79.2
O. niloticus	-	-	-	-
O. melanopleura	-	-	-	-
C. carpio	-	-	-	-
C. idella	-	-	-	-
A. nobilis	-	-	-	-
H. molitrix	-	-	-	-
C. catla	-	-	-	-
L. rohita	77 800 (85/86)	4.54 (86)	29.7 (86)	15.2
C. mrigala	35 000 (86)	-	-	-
L. dussumieri	-	-	-	-
C. chanos	-	-	-	-
E. auratensis	-	-	-	-
P. sarana	-	-	-	-
T. khudree	-	-	-	-
Others	-	-	-	-
Kandalama (780 ha)				
O. mossambicus	-	150.5 (83/86)	299.18 (83/86)	50.3
O. niloticus	-	-	-	-
O. melanopleura	-	-	-	-

Species	Stocking (number of fingerlings)	Production (t)	Total (t)	Percentage
C. carpio	-	-	-	-
C. idella	-	-	-	-
A. nobilis	97 000 (85)	5.66 (85)	726.5 (86)	4.42
H. molitrix	-	-	-	-
C. catla	-	-	-	-
L. rohita	337 000 (83/85)	106.5 (84/86)	247.7 (84/86)	42.97
C. mrigala	171 000 (86)	-	-	-
L. dussumieri	-	128.84 (83/86)	299.2 (83/86)	43.0
C. chanos	-	-	-	-
E. suratensis	-	-	-	-
P. sarana	-	15.3 (84)	35.1 (84)	43.58
T. khudree	-	-	-	-
Others	-	-	-	-
Dambulu Oya (417 ha)				
O. mossambicus	-	26.1 (84/86)	27.35 (84/86)	95.45
O. niloticus	25 000 (84)	-	-	-
O. melanopleura	-	-	-	-
C. carpio	-	-	-	-
C. idella	-	-	-	-
A. nobilis	-	-	-	-

Species	Stocking (number of fingerlings)	Production (t)	Total (t)	Percentage
H. molitrix	-	-	-	-
C. catla	-	-	-	-
L. rohita	9 250 (84)	0.346 (86)	8.51 (86)	4.06
C. mrigala	50 000 (86)	-	-	-
L. dussumieri	-	-	-	-
C. chanos	-	-	-	-
E. suratensis	-	-	-	-
P. sarana	-	-	-	-
T. khudree	-	-	-	-
Others	-	-	-	-
Parakrama Samudra **(2 262 ha**				
O. mossambicus	-	3 955.5 (78/86)	5 785.9 (78/86)	68.36
O. niloticus	25 500 (85)	377.32 (85/86)	663.4 (85/86)	56.9
O. melanopleura	-	17.53 (85/86)	663.4 (85/86)	-
C. carpio	5 000 (78)	-	5 785.97 (78/86)	-
C. idella	1 250 (86)	-	-	-
A. nobilis	55 500 (78/86)	-	5 785.97 (78/86)	-
H. molitrix	33 800 (86)	-	1 785.97 (86)	-
C. catla	-	-	-	-

Species	Stocking (number of fingerlings)	Production (t)	Total (t)	Percentage
L. rohita	223 600 (86)	4.6 (86)	343.3 (86)	-
C. mrigala	47 200 (86)	-	-	-
L. dussumieri	-	474 (78/86)	5 785.97 (78/86)	8.19
C. chanos	-	-	-	-
E. suratensis	-	-	-	-
P. sarana	-	-	-	-
T. khudree	-	-	-	-
Others	-	559.8 (78/86)	5 785.97 (78/86)	-
Kaudulla (2 591 ha)				
O. mossambicus	300 (78)	3 610 (79/87)	7 356.4 (79/87)	49.07
O. niloticus	4 000 (84)	214.6 (85/87)	3 990 (85/87)	5.6
O. melanopleura	-	-	-	-
C. carpio	6 000	9.7 (85)	1 417 (85)	-
C. idella	-	-	-	-
A. nobilis	-	-	-	-
H. molitrix	2 000 (84)	-	-	-
C. catla	4 000 (85)	-	-	-
L. rohita	10 000 (85)	-	-	-
C. mrigala	-	-	-	-

Species	Stocking (number of fingerlings)	Production (t)	Total (t)	Percentage
L. dussumieri	-	328.4 (79/85)	4 687 (79/85)	7.0
C. chanos	-	-	-	-
E. suratensis	-	-	-	-
P. sarana	-	1.86 (87)	-	-
T. khudree	-	-	-	-
Others	-	788 (79/87)	7 356.4 (79/87)	10.71
Minneriya (2 551 ha)				
O. mossambicus	104 000 (78/84)	3 896 (77/86)	6 788 (77/86)	57.4
O. niloticus	2 500 (85)	783.21 (85/86)	2 260.6	
O. melanopleura	-	-	-	-
C. carpio	10 200 (78/80)	-	-	-
C. idella	-	-	-	-
A. nobilis	90 000 (86)	0.6 (86)	1 175.5 (86)	-
H. molitrix	-	-	-	-
C. catla	-	-	-	-
L. rohita	-	-	-	-
C. mrigala	135 000 (86)	0.15 (86)	1 175.48 (86)	-
L. dussumieri	-	362 (77/83)	6 788 (77/86)	5.33
C. chanos	-	-	-	-

Species	Stocking (number of fingerlings)	Production (t)	Total (t)	Percentage
E. suratensis	-	-	-	-
P. sarana	-	670.55 (77/86)	6 788 (77/86)	9.88
T. khudree	-	-	-	-
Others	-	1 634 (77/86)	6 788 (77/86)	24.07
Pimburattewa (1 073 ha)				
O. mossambicus	12 000 (78/82)	2 915 (80/87)	3 880 (80/87)	75.12
O. niloticus	6 000 (81/85)	222.2 (86/87)	452.4 (86/87)	49.1
O. melanopleura	-	-	-	-
C. carpio	18 000 (78,84,87)	0.93 (87)	360.0 (87)	0.25
C. idella	-	-	-	-
A. nobilis	6 000 (85)	-	-	-
H. molitrix	86 000 (85/86)	-	-	-
C. catla	2 000 (85/86)	2.3 (87)	-	-
L. rohita	33 600 (85/86)	7 (87)	-	-
C. mrigala	128 000 (85/87)	-	-	-
L. dussumieri	-	500 (80/87)	3 880 (80-87)	12.9
C. chanos	-	-	-	-

Species	Stocking (number of fingerlings)	Production (t)	Total (t)	Percentage
E. suratensis	-	16.6	-	-
P. sarana	-	211.3 (80/87)	3 880 (80/88)	5.44
T. khudree	-	-	-	-
Others	-	504.81 (80/87)	-	-
Maduruoya (6 300 ha)				
O. mossambicus	3 000 (83)	1 794 (84/87)	2 585 (84/87)	69.4
O. niloticus	105 000 (83)	403.6 (85/87)	1 771.5 (85/87)	22.8
O. melanopleura	-	-	-	-
C. carpio	24 000 (83)	-	-	-
C. idella	-	-	-	-
A. nobilis	131 000 (83)	3.4	-	-
H. molitrix	-	-	-	-
C. catla	-	-	-	-
L. rohita	64 000 (83/86)	-	-	-
C. mrigala	-	-	-	-
L. dussumieri	-	68.3 (83/87)	2 585 (83/87)	2.6
C. chanos	5 000 (83)	-	-	-
E. suratensis	-	35.2 (83/87)	2 585 (83/87)	1.35
P. sarana	-	71 (83/87)	2 585 (83/87)	1.35
T. khudree	-	-	-	-
Others	-	177.8 (83/87)	2 585 (83/87)	6.9

Species	Stocking (number of fingerlings)	Production (t)	Total (t)	Percentage
Giritale (2 262 ha)				
O. mossambicus	34 000 (78/80)	121.7 (80/87)	359.6 (80/87)	33.84
O. niloticus	70 000 (83/84)	122.4 (85/87)	194.4 (85/87)	63
O. melanopleura	–	–	–	–
C. carpio	11 000 (84/87)	– (86/87)	155 (86/87)	2.5
C. idella	–	–	–	–
A. nobilis	365 000 (84/87)	62.4 (85/87)	194.4 (85/87)	32.09
H. molitrix	25 000 (84)	–	–	–
C. catla	–	–	–	–
L. rohita	148 000 (84/85/87)	36.6 (85/87)	194.4 (85/87)	18.8
C. mrigala	2 000 (85)	–	–	–
L. dussumieri	–	6.3 (80/82)	155.0 (80/82)	4.06
C. chanos	–	–	–	–
E. suratensis	–	–	–	–
P. sarana	–	53.03 (80/87)	359.6 (80/87)	15
T. khudree	–	–	–	–
Others	–	31.4 (80/87)	399.7 (80/87)	7.85

Species	Stocking (number of fingerlings)	Production (t)	Total (t)	Percentage
Tabbowa (500 ha)				
O. mossambicus	32 000 (80/87)	2 714.7 (84/87)	2 855.77 (84/87)	95.06
O. niloticus	-	-	-	-
O. melanopleura	-	-	-	-
C. carpio	-	-	-	-
C. idella	400 (82)	-	-	-
A. nobilis	27 800 (82/87)	-	-	-
H. molitrix	5 000 (87)	-	-	-
C. catla	-	-	-	-
L. rohita	30 800 (83/87)	136.2 (84/87)	2 855.77 (87)	4.76
C. mrigala	18 180 (87)	-	-	-
L. dussumieri	-	-	-	-
C. chanos	11 400 (80/87)	12.6 (84/87)	2 855.77 (84/87)	-
E. suratensis	-	-	-	-
P. sarana	-	-	-	-
T. khudree	-	-	-	-
Others	-	-	-	-

Species	Stocking (number of fingerlinga)	Production (t)	Total (t)	Percentage
Kalawewa/Balaluwewa (2 900 ha)				
O. mossambicus	-	1 713.06	2 358.25 80/83	72.7
O. niloticus	-	-	-	-
T. melanopleura	-	-	-	-
C. carpio	-	-	-	-
C. idella	-	-	-	-
A. nobilis	-	-	-	-
H. molitrix	-	-	-	-
C. catla	-	-	-	-
L. rohita	11 000 (83)	-	-	-
C. mrigala	-	-	-	-
L. dussumieri	-	492.08	2 358.25 (80/83)	20.7 (80/83)
C. chanos	-	-	-	-
E. suratensia	-	-	-	-
P. sarana	-	-	-	-
T. khudree	-	-	-	-
Others	-	153.11 (80/83)	2 358.25 (80/83)	6.6

Species	Stocking (number of fingerlings)	Production (t)	Total (t)	Percentage
Rajangana (1795 ha)				
O. mossambicus	-	2 750.57 (80/83)	3 338.18 (80/83)	82.4
O. niloticus	-	-	-	-
T. melanopleura	-	-	-	-
C. carpio	-	-	-	-
C. idella	-	-	-	-
A. nobilis	-	-	-	-
H. molitrix	-	-	-	-
C. catla	-	-	-	-
L. rohita	-	-	-	-
C. mrigala	-	-	-	-
L. dussumieri	-	587.61 (80/83)	3 338.18 (80/83)	17.6
C. chanos	-	-	-	-
E. suratensis	-	-	-	-
P. sarana	-	-	-	-
T. khudree	-	-	-	-
Others	-	-	3 338.18 (80/83)	-
Nachchaduwa (2 003 ha)				
O. mossambicus	-	1 262.44 (81/83)	1 574.28 (81/83)	80.2
O. nilitocus	-	-	-	-
T. melanopleura	-	-	-	-

Species	Stocking (number of fingerlings)	Production (t)	Total (t)	Percentage
C. carpio	-	-	-	-
C. idella	-	-	-	-
A. nobilis	-	-	-	-
H. molitrix	-	-	-	-
C. catla	-	-	-	-
L. rohita	-	-	-	-
C. mrigala	-	-	-	-
L. dussumieri	-	311.84 (81/83)	1 574.28 (81/83)	19.8
C. chanos	-	-	-	-
E. suratensis	-	-	-	-
P. sarana	-	-	-	-
T. khudree	-	-	-	-
Others	-	-	-	-
Mahakandarawa (1 181 ha)				
O. mossambicus	-	509.0 (80/83)	621.51 (80/83)	81.9
O. niloticus	-	-	-	-
T. melanopleura	-	-	-	-
C. carpio	-	-	-	-
C. idella	-	-	-	-
A. nobilis	-	-	-	-

Species	Stocking (number of fingerlings)	Production (t)	Total (t)	Percentage
H. molitrix	-	-	-	-
C. catla	-	-	-	-
L. rohita	-	-	-	-
C. mrigala	-	18.13 (80/83)	621.51 (80/85)	2.9
L. dussumieri	-	-	-	-
C. chanos	-	-	-	-
E. suratensis	-	-	-	-
P. sarana	-	-	-	-
T. khudree	-	-	-	-
Others	-	13.38 (80/83)	621.51 (80/83)	2.2
Mahavilachchiya (1 091 ha)				
O. mossambicus	-	1 741.26 (80/83)	1 983.29 (80/83)	87.8
O. niloticus	-	-	-	-
T. melanopleura	-	-	-	-
C. carpio	-	-	-	-
C. idella	-	-	-	-
A. nobilis	-	-	-	-
H. molitrix	-	-	-	-
C. catla	-	-	-	-
L. rohita	-	-	-	-
C. mrigala	-	-	-	-

Species	Stocking (number of fingerlings)	Production (t)	Total (t)	Percentage
L. dussumieri	–	215.26 (80/83)	1 983.29 (80/83)	10.9
C. chanoa	–	–	–	–
E. auratensis	–	–	–	–
P. sarana	–	–	–	–
T. khudree	–	–	–	–
Others	–	26.77 (80/83)	1 983.29 (80/83)	1.3
Huruluwewa (2 386)				
O. moasambicus	–	556.11 (80/83)	675.24 (80/83)	82.4
O. niloticus	–	–	–	–
T. melanopleura	–	–	–	–
C. carpio	–	–	–	–
C. idella	–	–	–	–
A. nobilis	–	–	–	–
H. molitrix	–	–	–	–
C. catla	–	–	–	–
L. rohita	–	–	–	–
C. mrigala	–	–	–	–
L. dussumieri	–	78.08 (80/83)	–	11.6
C. chanos	–	–	–	–
E. suratensis	–	–	–	–
P. sarana	–	–	–	–
T. khudree	–	–	–	–
Others	–	41.05 (80/83)	675.24 (80/83)	6.0

Indian carps have been stocked in the reservoirs since 1983. Only rohu (L. rohita) has started appearing in the commercial catches in any significant quantity. The contribution of this species to the commercial catch was 13.56 t in Tabbowa reservoir (500 ha) in 1986-1987 as compared to 1 465.3 t of tilapia in the same year. In Inginimitiya reservoir 12.8 t of rohu and 331.3 t of tilapia have been produced in 1987. Encouraging results have been obtained in Kandalama (794 ha), Devahuwa (3284 ha) and in Giritale (2 262 ha) where the contribution of rohu to the commercial fish catch was 43%, 15% and 19% respectively, based on the data for 1985 to 1987. In Bowatenne reservoir (550 ha) the production of rohu reached 38.48% in 1987. Illukkumbura (1986) reported the appearance of rohu in the fish catches of Udawalawe (3 374 ha) six months after stocking and at Kandalama (794 ha) 8 months after stocking. In both reservoirs rohu has attained a weight over 1 kg within a year.

The hill country reservoirs (elevation 1 500 m - 1 600 m) have been stocked with tilapia, common carp and exotic carps. Tilapia dominates the yield, followed by L. dussumieri and P. sarana. In some reservoirs common carp and mahseer (Tor khudree) also contribute significantly. However, the proportion of indigenous species in fish catches has been declining.

Gregory Lake (30 ha, elevation 1 848 m) in Nuwara Eliya has beenstocked with common carp in the early days. There is very little commercial fishing in this reservoir, but when the reservoir was drained for dredging in 1978 large quantities of common carp were caught. The author observed a large number of common carp eggs attached to submerged aquatic vegetation in some parts of the reservoir in 1978. In Kotmale reservoir (250 ha) and Kande Ela reservoir (70 ha) the major species caught is common carp.

Polgolla reservoir (120 ha, elevation 350 m) has P. sarana and mahseer in equal quantities in the catch (12%). In this reservoir only insignificant numbers of Labeo fisheri, Ophiocephalus and Glossogobius giuris appear in the catch.

4. ROLE OF INDIGENOUS SPECIES

Important species of indigenous carps which contribute to the commercial catch are P. sarana and L. dussumieri. Except for the few L. dussumieri that had been stocked by the Ministry of Fisheries in some reservoirs, generally no artificial stocking of indigenous species is carried out.

The data available for several reservoirs indicate that the production of indigenous species such as L. dussumieri, P. sarana and Tor khudree (mahseer) has been decreasing over the years. Tilapia has been the dominant species in the catch. In Nagadeepa reservoir (318 ha) there had been a significant production of L. dussumieri prior to 1983. In 1983 the contribution of this species reached 40% of the total catch, and it was second only to O. mossambicus. In 1986, L. dussumieri represented 6.57% and the proportion of endemic carps in the fish catch declined.

In Castlereigh and Maussakelle reservoirs mahseer contributed 17.6% (1979-1987 average) to the total catch, while tilapia contributed 80%.

Commercial catches of P. sarana and L. dussumieri in reservoirs are known to be significant during several months of the year when these species migrate into the inflowing rivers for breeding (De Silva, 1983, 1985). Illukkumbura (1986) observed declining production of L. dussumieri in Kandalama reservoir since 1983, due to the possible competition for the food with the newly introduced rohu.

In the seven major reservoirs in Matale District, P. bimaculatus, R. daniconius, L. porcellus lankae have been recorded, but L. dussumieri dominated the cyprinids, with 16 to 25% of their total in 1983. Composition of indigenous carps has gradually decreased reaching the present level of 0.1%.

In fish catches from 7 major reservoirs in Anuradhapura District for 1981 L. dussumieri contributed 41.7%, 32.7% and 16.7% in Kalawewa (2 552 ha), Balaluwewa (1 768 ha) snd Nachchaduwa (1 768 ha) reservoirs, respectively. The flushing rate in these reservoirs has increased as a result of the Mahaweli Diversion Scheme. It seems that at present riverine conditions prevail in these reservoirs.

Commercially important indigenous species breed in the inflowing rivers into which they migrate (De Silva 1985a).

5. PERFORMANCE OF EXOTIC CARPS IN RESERVOIRS

O. mossambicus and C. carpio were the two major species introduced into the reservoirs in the early days of reservoir fishery development. Tilapia, a prolific breeder, is present in almoat all the water bodies in Sri Lanka and is the most important constituent of fish catches. Common carp which also breeds naturally does not contribute to the commercial catch except in a few hill country reservoirs, despite the release of large numbers of fry into the reservoirs to supplement natural recruitment.

De Silva (1983) is of the view that in perennial reservoirs which are relatively large (>250 ha) extensive culture operations are unlikely to aucceed and that their fishery should be based on self sustaining fish stocks.

The failure of introduced carps has been attributed to biological and logistical factors. Among the major reasons is the damming of the rivers resulting in conditions unsuitable for spawning of the introduced carps. De Silva (1983) is of the view that stocking and harvesting should ensure a return of at least 30%-40% to make it viable and that artificial stocking should supplement natural recruitment. It has been argued that a fishery based on periodical stocking is likely to be unprofitable and almost meaningless in the context of Sri Lankan conditions. According to De Silva (1988) stocking of Chinese carps and Indian major carps has produced very limited results. Sirisena and De Silva (1987) state that all evidence indicates that stocking of perennial reservoirs in Sri Lanka, especially with subtropical riverine Chinese and Gangetic carps, ia not commercially viable nor scientifically justified.

Failure of common carp to contribute significantly to the catch from reservoirs may be attributed to its failure to establish itself or to the method of fishing. This species is a bottom dweller and only a few individuals may come to the surface waters in the shore areas where vegetation is present for spawning. The author has observed common carp in running condition at Gregory Lake, Nuwara Eliya, in 1978. This is a high altitude reservoir. During the time when the water was drained for dredging the lake, some of the fish caught were fully ripe. Eggs were seen attached to the vegetation in shore areas. Similar observations have been reported by Chandrasoma (1983) for two other reservoirs.

Although common carp, a bottom dweller, may be established in some reservoirs it may not be caught with traditional gill nets. No bottom gear is used due to the presence of various obstacles such as tree stumps.

Sreenivasan (1982) describes the merits of stocking of Indian carps in reservoirs. He recommends that Chinese carps such as silver carp and grass carp would be suitable for Sri Lankan reservoirs. He states that unless adequate spawning stocks are maintained in large water bodies there is little scope for sound stocks to develop. Either by overexploitation or understocking the spawning population may be so low as to hinder the reproductive response. This might be another reason for the poor performance of Indian carps in Sri Lanka. Sreenivasan (1982) and Sreenivasan and Thayaparan (1983) recommend stocking silver carp in low country reservoirs and the new Mahaweli reservoirs. They are of the view that to facilitate breeding of major carps water should be discharged from upper reservoirs to provide a stimulus for the fish in the downstream reservoirs to spawn. They recommend that the stocking size be not less than 15 cm and if predators are present the size should be larger to enable higher survival. The opinion of the Chinese experts with regard to stocking of Chinese carps in reservoirs was similar.

6. MINOR CYPRINID FISHERY RESOURCE

The fish fauna in Sri Lanka has a significant number of minor cyprinid species which do not grow on an averge above 15 cm and some species which grow to a maximum size of 7-10 cm. Only about 8 species have colonized the vast reservoir habitats created by man (Sirisena and De Silva, 1987). The smaller indigenous species such as P. dorsalis, P. filamentosus, P. chola, Danio equipinatus , Amblypharyngodon melettinus, Ophiocephalus, cat fishes and eels remain underexploited or unexploited (De Silva, 1985) (Table 2).

De Silva (1983) has observed coexistence of a gill net fishery for O. mossambicus and other species such as P. sarana with another fishery for minor barbs without any ill effect on each other, at least in two reservoirs, i.e. Mahavilachchiya and Nachchaduwa. He suggested that in most reservoirs a secondary fishery could be developed for these species. He based his hypothesis on the behaviour of minor cyprinids during their maturity. He stated that the minor cyprinids though small in size move into deeper waters or away from the littoral and inhabit areas similar to those of adult O. mossambicus. Therefore, a selective gill net fishery could be adopted without any apparent detrimental effect on O. mossambicus young or pre-recruits.

Table 2

Species of minor cyprinids recorded in
the reservoirs of Sri Lanka
(Sirisena and De Silva, 1987)

Labeo dussumieri	Contributes to existing commercial fisheries of most reservoirs.
B. sarana	Contributes to existing commercial fisheries of most reservoirs.
B. chola	Throughout the island but restricted to certain reservoirs.
B. dorsalis	Throughout the island.
B. filamentosus	Restricted colonization.
B. ticto	Confined to reservoirs in central and eastern parts of Sri Lanka.
Rasbora daniconius	Throughout the island.
Danio equipinnatus	Not recorded in large numbers. Reservoirs in southern parts of the island.
Amblypharyngodon melettinus	Common in most reservoirs throughout the country.

The existence of appreciable quantities of minor cyprinids was initially documented during the Austrian-Sri Lanka study on Parakrama Samudra (Schiemer and Hofer, 1983). De Silva and Sirisena (1987) stated that there were differences between the reservoirs and likelihood of the existence of certain species associations. They recommended a small-scale gill net fishery, utilizing a mesh size of 15 mm and 30 mm (depending on the reservoir), which could be initiated without an apparent ill-effect on *O. mossambicus* fishery.

Based on the results of evaluation of multi-mesh gill net experimental trials carried out by Sirisena and De Silva (1987a) in five reservoirs in Hambantota District, it has been pointed out that in all the reservoirs minor cyprinids accounted for more than 50%. However, the extent of catches varied from reservoir to reservoir. The data have also indicated that the minor cyprinid catches exceed the existing *O. mossambicua* commercial catches by ten-fold in certain reservoirs. The species of cyprinids caught are *A. melettinus*, *R. daniconius*, *B. filamentosus*, *B. chola*. According to them a fishery for minor cyprinids could be effectively introduced in Sri Lankan reservoirs, perhaps doubling the total yield.

Initially, minor cyprinids may not be readily accepted for human consumption. As there is a growing need for fish meal for aquaculture industry, the minor cyprinid resources could be effectively utilized to meet such demands. A well managed fishery for exploitation of minor cyprinids could lead to an increase in fish production.

7. CAGE CULTURE OF CARPS IN RESERVOIRS

Initial trials in cage culture with the Chinese carps in Sri Lanka were not successful due to small initial size of fingerlings used for stocking of the cages, susceptibility to diseases and need for feeds with comparatively higher protein content.

Trials conducted at Udawalawe, Thalgaswela and Wennappuwa showed that Chinese carps and Indian carps with initial stocking size ranging from 5 g to 20 g exhibited a poor growth rate reaching average sizes of 40 g to 70 g in 7-8 months. At Wennappuwa tank, bighead carp exhibited a comparatively better growth rate at a stocking density of 20 fish/m^3 reaching an average size of about 200 g in 6-7 months. Similar results were obtained in the Thalgaswela tank with bighead carp when the initial stocking size of fingerlings of bighead carp was over 25 g. Indian carps, especially rohu, exhibited a poor growth rate in cages, both at Udawalawe and Thalgaswela.

The reasons for poor growth of Indian and Chinese carps may have been the inadequate supply of plankton in the reservoirs in which cage culture was carried out and small size of fingerlings which need abundant supply of plankton especially zooplankton for their initial growth. Their response to artificial diets during these stages is poor as a result of which the growth of carps during the initial stages is slower in cages when compared to the growth in ponds. Results from trials in cage culture conducted in other Southeast Asian countries show that, to obtain a fairly large size of carps, the initial stocking size and density should be around 50-75 g and less than 20 fish/m^3 respectively (Weerakoon, pers.com.).

8. HARVESTING OF CARPS

Boats are manually propelled fibre glass canoes and wooden canoes operated by 2-3 fishermen. The commonly used fishing gear is a gill net with mesh ranging from 76 to 140 mm. Gill nets are set from the surface down to a depth of 2 m. Generally, they are set in the evening and collected in the following morning. Each fisherman uses 4-5 net sets. The nets efficiently capture tilapias, but carps are rarely captured. In some areas such as Puttalam, the fishermen have experienced a better catch when the water level is low. In Iranamadu tank, carps are harvested at a low water level. Carps are also caught when the sluice gates of the reservoirs are open for irrigation purpose. In Hambantota District in tanks where submerged trees are a problem, the net consisting of 6 panels is halved, each panel being 27-40 mesh deep (Beveridge et al., 1986).

9. MARKETING OF EXOTIC CARPS

Price of carps varies in different districts (Table 3). In Anuradhapura District there is a good market for carp species. It has been reported that carps weighing 2-4 kg fetch a better price than 5-7 kg ones. In some areas the price is Rs.8/kg near the reservoirs and Rs.10/kg in the market. The price of carps from reservoirs in Puttalam District varies from Rs.10/kg to Rs.12/kg. The price in the urban markets is Rs.20 to Rs.25/kg.

Table 3

Price of exotic carps in different districts

District	Price of carps (Rs./kg)
Anuradhapura	8 _ 18 (15-20)*
Badulla	5 - 7
Matale	8 - 10 (20)*
Nuwara Eliya	15 - 26 (35)*
Northern	10 - 12
Polonnaruwa	8 - 10
Puttalam	80 - 102 (20-25)*

* Retail price (in brackets)

In Polonnaruwa District fishermen sell their catch mainly to bicycle vendors and lorry traders who call at reservoirs. Selling price of fish is the same at the reservoirs irrespective of the species. The price of fish is Rs.10/kg for the reservoirs which are located near the village centres or towns and Rs.8/kg for the remote reservoirs like Pimburattewa and Maduru Oya. The bicycle vendors sell their purchase to local consumers whereas the lorry traders distribute it among retailers in cities such as Colombo, Kandy, Kurunegala and Matale. According to the fishermen the demand for new fish (exotic carps) is less than that for tilapia and indigenous fish.

In the upland reservoirs in Nuwara Eliya District the fish brought by the bicycle vendors are sold at retail price. Some of the vendors take fish to interior places while others sell them at fish stalls. Carps fetch a higher price in Castlereigh and Maussakelle. Price of tilapia has increased from Rs.3.50/kg in 1978 to Rs.25/kg in 1987. Price of carps has increased from Rs.4/kg (1978) to Rs.32.50/kg (1987) in Castlereigh and Rs.12/kg (1981) to Rs.25/kg (1987) in Maussakelle.

In Matale District, generally the total fish catch is sold at the reservoir to the fish vendors. There is a small surplus during February-September when the fishermen dry the fish. Fish vendors regularly buy fish from the fishermen and pay at the time of buying. Usually one fish vendor purchases the catch of more than five fishermen. Some fish vendors sell the fish at doorsteps. A significant number of fishermen use scooters and transport the fish to distant places and sell at wholesale prices to the people who own stalls in small towns. This method does not require refrigeration facilities. Tilapia and carp fetch the same price. Price has increased from Rs.4.50/kg and Rs.9/kg wholesale and retail respectively in 1978 to Rs.10/kg to Rs.20/kg in 1988.

In the Northern Province about 20% of the catch is sold fresh and the balance is salted or processed into dried fish.

In Hambantota District usually 1-2 kg of fish is retained by the fishermen for domestic consumption and for distribution to the families of helpers and neighbours. The rest is sold by the fishermen themselves or to cycle vendors. All the fish is sold wet and a high proportion is sold in the immediate vicinity of the tanks although a portion is also transported to more distant markets. Price of fish varies from Rs.3 to 10/kg depending on the species, size, season and location.

10. CONSTRAINTS IN CARP PRODUCTION

Carp production in reservoirs has several constraints. The quantity of seed produced for stocking at the breeding stations is highly insufficient to cater to the requirements. Although fry are produced in large numbers there are no adequate rearing ponds in the stations to produce the required large number of fingerlings. Very often aquaculturists are compelled to adopt high stocking densities in the nursery ponds. Therefore many of the reservoirs are stocked only with a small number of carp fingerlings. Stocking size of tilapia and common carp is usually 5-6 cm and 4-8 cm respectively. The stocking size of Indian and Chinese carp fingerlings ranges between 5 and 7 cm. Stocking of perennial reservoirs with large sized fingerlings has been recommended by the Chinese experts.

Although a large number of fingerlings have been stocked in some reservoirs the recovery rate is very poor ranging from zero to 5%. Poor recovery may be attributed to poor survival of the fish stocked and/or to inefficient harvesting methods. The exotic carp fingerlings may not be able to compete for food and space in reservoirs with well established species such as O. mossambicus, O. niloticus, E. suratensis.

It is also possible that the harvesting methods adopted in reservoirs are not suitable for catching exotic carps. At present the main target species of fishermen is tilapia which has a ready market. The gill nets used by them may be good for tilapia but too small for exotic carps. With this type of nets the carps get entangled not in the mesh, but in the entire net. The mostly used netting material in reservoirs is of two ply which is not strong enough to retain carps. Also, as the gill nets hang down to a depth of only about 2 m, their impact on bottom dwelling carps like mrigal and common carp may be very little.

Common carp is not popular in some areas due to the large number of small bones it has. The high fat content in the Chinese carps occasionally caught in the reservoirs makes them unattractive for consumption. In some areas of the country there is less consumer preference for Chinese carps when compared to tilapia.

The names of exotic carps are still strange to the fishermen. Some fish are sold as marine fish by giving them names of common sea fish such as mullet. It has been suggested that easily pronounceable common names be given to the exotic carps and these are popularised among the reservoir fishermen. Already, tilapia has been given the name "wew seer" (lake mackerel).

An extensive publicity programme has been launched to popularise recently introduced exotic carps among the people. The programme is oriented towards motivation of people to undertake fish farming and increase carp consumption in the urban as well as in the rural areas.

11. CONCLUSIONS

At present common carp, Chinese carps and some species of Indian carps do not appear in the commercial fish catches, or their contribution is insignificant in many larger reservoirs in Sri Lanka. Among the Indian major carps only rohu has started appearing in the commercial fish catches to any significant extent and that too only in a few isolated reservoirs. Presence of obstacles such as tree stumps and the nature of bottom topography of the reservoirs prevent the use of bottom drag nets for catching these species. The low recovery rate of these species may be due to small size of fingerlings stocked, low survival rate of fingerlings, inability of the exotic carps to compete for food and space in reservoirs with well established species such as O. mossambicus, O. niloticus, and P. sarana. Harvesting methods which are mainly aimed at catching tilapia do not seem to work well for exotic carps. The economics of stocking of carps in reservoirs has to be studied. Careful monitoring of large size fingerlings stocked in a few selected reservoirs is needed to obtain information on growth and mortalities. Fishing trials using different types of nets and careful investigations of factors mentioned hitherto are also needed.

Selective gill net fishery for abundant minor cyprinid resources should be tested on a large scale in several large reservoirs. Regulatory aspect of this activity will have to be resolved and effective management strategies should be worked out in harnessing this resource.

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THE USE OF CYPRINIDS IN FISHERIES MANAGEMENT OF THE LARGER INLAND WATER BODIES IN THAILAND

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1. INTRODUCTION

Cyprinids are very common freshwater fish to the Thais. They are most numerous as to species and most abundant as to individuals among freshwater fish of Thailand. Approximately 250 species of cyprinids (including minnows) thrive in Thai waters. They range from a few centimeters to over 2.50 m in total length (Catlocarpio siamensis). Regardless of size, they are eaten and on account of their general abundance and ease to capture they constitute an important element in the food supply. Many species such as Probarbus jullieni, Tor tambroides and Cyclocheilichthys enoplos are highly esteemed as food and command high price in local markets. Several species are attractive ornamental fish such as Rasbora heteromorpha, Puntius schwanenfeldi, P. altua, Balantiocheilus melanopterus, Labeo bicolor and L. erythrurus. These ornamental fishes are popular among aquarium lovers both in and outside the country.

Several species of carps had been introduced into Thailand, mainly for aquaculture. The following is a list of exotic species that were introduced and aucceasfully acclimatized in ponds, lakes and reservoirs. Year of introduction and country of origin are shown in parenthesis (from Duangswasdi and Pupipat, 1982): Cyprinus carpio (approx. 1920, China); Aristichthys nobilis, Hypophthalmichthys molitrix snd Ctenophsryngodon idella (1922, China); Labeo rohita (1968, India); Catla catla (1979 , Bangladeah); Caraasiua carassius (1980, Japan); and Cirrhinus mrigala (1980, India). Common carp, Chinese carps and rohu have fulfilled the objectives of the introduction.

Common carp, rohu and Chinese carps have significantly contributed to annual landings and are the most productive species (Table 1). The other introduced species have not yet been recognized in the catches in spite of some species showing very good growth rate and promise.

2. SEED PRODUCTION, STOCKING AND RETURNS

The production of carp fingerlings for stocking is the responsibility of the Thai Department of Fisheries (DOF). DOF runs 30 freshwater fisheries stations throughout the country. These stations have their own hatchery to produce finfish and shellfish fry and fingerlings for stocking and for culture. The annual production capacity of these hatcheries is estimated at 200 million fish fingerlings of various species. The annual production of carp fingerlings for the last 10 years is shown in Table 2.

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Table 1. Annual landings (metric tons) and value (million Baht) of cyprinids from lakes and reservoirs in Thailand (1984-1985)

Species	1984		1985	
	Quantity	Value	Quantity	Value
Indigenous cyprinids				
Puntius gonionotus	5,825.48	127.738	7,714.76	160.953
Probarbus jullieni	8.73	0.247	129.42	2.995
Cirrhinus jullieni	6,185.06	83.697	3,450.22	57.982
Morulius chrysophekadion	242.80	3.392	5.09	0.095
Cyclocheilichthys enoplos	110.80	1.774	48.00	0.783
Osteochilus hasselti	502.26	8.712	1,659.44	32.862
Puntioplites proctozysron	806.76	10.086	58.89	0.909
Hampala spp.	2,188.83	41.130	1,291.14	19.841
Labiobarbus spp.	63.64	0.593	128.19	1.283
Cirrhinus microlepis	14.17	0.509	93.89	2.359
Puntius orphoides	6.05	0.064	39.90	0.431
Cyclocheilichthys apogon	1.28	0.019	1.35	0.024
Sub-total	15,955.86	277.961	14,620.29	280.517
Exotic carps				
Cyprinus carpio	702.26	11.996	776.21	19.675
Labeo rohita	538.67	11.478	481.63	12.410
Chinese carps	377.79	20.976	364.81	9.051
Sub-total	1,618.72	34.450	1,622.65	41.136
Total	17,574.58	312.411	16,242.94	321.653
Total yield	46,009.19	1,008.781	49,750.73	1,094.366
Percentage of cyprinids in landings	38.20	30.97	32.65	29.39

Source: Fisheries Statistics Sub-Division

Table 2. Seed production of carps in DOF hatcheries (1977–1986)

Species	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Cyprinus carpio	8,389,652	16,814,015	16,437,115	16,939,715	13,055,655	12,239,925	9,982,961	10,723,970	13,375,977	18,560,526
Puntius gonionotus	12,027,575	31,548,075	35,747,030	32,240,690	39,472,785	28,178,850	38,908,796	46,502,610	58,564,172	63,130,268
Labeo rohita	5,070,540	8,903,250	13,559,885	14,533,818	18,794,380	16,148,419	21,928,609	26,138,846	25,618,096	29,824,608
Chinese carps	406,000	828,706	2,033,080	548,855	710,076	487,395	436,250	NA	874,413	769,870
Total	25,893,767	58,094,046	67,777,110	64,263,078	72,032,896	57,054,589	71,256,616	83,365,426	98,432,658	112,285,272

Source: Fisheries Statistics Sub-Division

Carps are mainly cultured in earthen ponds. None have been cultured in cages and pens except in scientific experiments. The aquaculture carp production for the last 10 years averaged 14.45% of the total production from freshwater aquaculture. It shows an increase from 2 527.07 t in 1977 to 6 392.82 t in 1981, 13 279.60 t in 1986. Its value increased from 37.76 million baht in 1977 to 243.69 million baht in 1986 (Table 3).

Fish stocking of lakes and reservoirs has been practised in Thailand since the 1950s. Initially, 22 lakes and irrigation tanks in the northeast were stocked with freshwater fishes, such as Thai silver carp, Puntius gonionotus (Ling, 1957). Thereafter, fish were stocked ocassionally in certain lakes and reservoirs mainly for improving fish production. Thai silver carp and Chinese carps (grass, bighead, silver) are popular among stocked species. The purpose of stocking carps into large water bodies was to suppress the growth of aquatic vegetations, to utilize all trophic levels available, and to increase fish yield.

Regular fish stocking was initiated in 1978 with the establishment of the "Nation-wide Fish Stocking Programme". Millions of fish and shellfish are annually stocked in several hundred thousand hectares of water bodies all over the country. Carps are the major group of fish species stocked in lakes and reservoirs under this programme. Details are given in Table 4.

Indigenous carps and minnows represent a major portion of annual fish landings from freshwater capture fisheries of Thailand. According to data available, on an average, cyprinids contributed 66.40% to annual landing taken from floodplain fisheries in Central Plains during 1964-1970 (Tongsanga and Kessunchai, 1964, 1965; Pinyoying, 1964; Sidthimunka and Saenglert, 1967; Nimsomboon and Tongmee, 1970). On the average, carps and minnows represented 42% of the value from capture fisheries in the natural lake Bung Borapet (20 000 ha) in Central Plains during 1964-1975 (Bhukaswan, 1977). In Ubolratana reservoir (41 000 ha) carps and minnows contributed between 19.29 and 80.54% of annual landings (Table 5) with an average of 68.1%. Recent statistical surveys on freshwater fish landings from lakes and reservoirs all over the country showed that carps and minnows contributed on average 35.43% of the total annual catch (Table 1).

3. ECONOMICS AND MARKETABILITY OF CYPRINIDS

Carps are the major group of freshwater fish being stocked in lakes and reservoirs in Thailand. A number of carp fingerlings stocked annually ranged between 31 457 380 fish (47.44%) of all species stocked in 1981 to 49 739 470 fish (68.37%) in 1965, with an average in the last 7 years of 42 232 700 fish or 61.38% of all species stocked (Table 4). The cost of carp fingerling production was estimated 0.07 baht/fish, thus the annual cost of production of carp fingerlings for stocking varied from 2.20 million baht in 1981 to 3.48 million baht in 1985 with the last 7 years average being 2.96 million baht (25 baht = 1 US $).

Table 3. Cultivated cyprinids, their annual production (metric tons) and value (million Baht) in Thailand during 1977-1986

Species	1977		1978		1679		1980		1981		1982		1983		1984		1985		1986	
	Ton	Value	Ton	Value	Ton	Value	Ton	Value	Ton	Value	Ton	Value	Ton	Value	Ton	Value	Ton	Value	Ton	Value
Puntius gonionotus	825.59	6.70	1,711.95	21.29	5,682.83	32.34	2,632.52	31.85	4,177.67	75.80	4,630.56	86.32	5,651.65	105.74	4,914.28	94.40	7,512.61	137.65	6,791.21	154.38
Cyprinus carpio	758.24	15.41	768.72	14.54	784.20	17.72	1,257.10	32.21	1,258.77	31.51	1,477.98	39.87	1,914.43	53.40	1,211.70	33.89	1,549.0	42.68	1,858.50	47.46
Probarbus jullieni	0.48	0.02	0.29	0.01	2.28	0.05	23.80	0.53	28.55	0.37	64.79	1.03	129.03	2.12	16.76	0.40	8.95	0.17	0.83	0.02
Labeo rohita	8.68	0.25	37.83	0.49	107.74	2.35	153.86	3.12	109.63	2.79	175.63	4.70	501.79	14.07	489.09	10.67	795.65	16.27	754.91	14.26
Chinese carps	634.08	12.38	1,311.14	17.82	1,091.01	14.81	750.03	11.75	818.20	14.23	923.02	14.24	856.59	13.29	1,220.01	18.67	1,011.13	12.93	1,772.67	22.99
Cirrhinus mrigala	-	-	-	-	-	-	-	-	-	-	-	-	1.76	0.04	2.86	0.08	80.64	1.92	101.18	2.55
Sub-total	2.527.07	37.76	5,816.63	54.15	5,468.06	87.25	5,097.11	98.46	6,392.82	122.70	7,269.78	146.26	9,055.23	186.66	7,654.72	158.11	10,757.48	211.62	13,279.60	243.69
All species production	35.142.38	415.69	59,366.67	426.58	29,461.74	436.16	34,504.56	598.91	48,123.12	1,006.04	45,829.43	880.03	46,966.39	1,005.58	50,410.90	1,226.36	73,254.05	1,363.17	89,325.09	1,953.05
Percentage of carps	7.62	9.08	6.70	12.69	19.24	20.00	14.77	16.44	15.29	12.20	15.86	16.62	19.28	16.56	15.58	12.89	14.29	15.52	14.87	12.59

Source: Fisheries Statistics Sub-Division

Table 4. Annual cyprinid stocking in lakes and reservoirs in Thailand (1978-1987)

Fish species		Annual Stocking									
		1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Indigenous cyprinids											
Puntius gonionotus		✓	23,255,330	20,575,388	15,936,360	✓	25,853,340	✓	32,553,925	24,247,699	22,048,940
Probarbus jullieni		✓	452,385	599,000	967,820	✓	25,000	-	6,000	-	-
Cirrhinus jullieni		✓	800,000	-	-	-	-	-	-	-	-
Morulius chrysophekadion		-	2,000	105,000	75,000	✓	135,900	-	-	-	-
Puntius schwanenfeldi		-	-	1,000	-	-	-	-	-	-	-
Cyclocheilichthys enoplos		-	-	-	-	-	-	-	30,000	-	-
Leptobarbus hoeveni		-	-	-	-	-	-	-	400	-	-
Catlocarpio siamensis		-	-	-	-	-	-	✓	1,200	-	11,273
Osteochilus hasselti		✓	-	-	-	-	-	-	-	-	-
Puntioplites proctozysron		-	-	-	-	-	100,000	-	-	-	-
Sub-Total		?	24,509,715	21,280,388	16,979,380	?	26,114,240	?	32,593,525	24,247,699	22,060,213
Exotic carps											
Cyprinus carpio		✓	7,388,775	9,421,600	5,080,050	✓	8,035,950	✓	8,315,399	6,787,300	7,389,037
Labeo rohita		✓	9,149,920	8,368,500	8,883,050	✓	10,636,570	✓	7,457,699	9,182,950	10,253,709
Hypophthalmichthys molitrix *Aristichthys nobilis* *Ctenopharyngodon idella* }		✓	872,500	813,420	514,900	✓	626,688	✓	475,348	1,077,600	1,143,051
Cirrhinus mrigala		-	-	-	-	-	21,000	✓	897,500	1,821,530	3,221,209
Catla catla		-	-	-	-	-	10,000	-	-	-	-
Sub-Total		?	17,411,195	18,603,520	14,478,000	?	19,330,208	?	17,145,946	18,869,380	22,007,006
Total		?	41,920,910	39,883,908	31,457,380	?	45,444,448	?	49,739,471	43,117,079	44,067,219
Grand Total (annual fish and shellfish stocking)		69,762,977	67,710,345	59,627,771	66,315,000	83,200,000	81,569,291	61,776,474	72,752,747	64,783,146	70,211,276
percentage of cyprinids in grand total stocking		?	61.91	66.89	47.44	?	55.71	?	68.37	66.56	62.76
Large water bodies	Number	1,936	1,717	2,032	2,332	1,482	1,860	1,482	1,498	1,965	1,738
	Surface area (ha)	746,377	802,081	531,474	304,206	332,242	596,180	332,242	647,657	537,348	747,031

Remarks: ✓ stocking ; ? no information

Table 3. Cyprinids in commercial catches (metric tons) from Ubolratana Reservoir, Khon Kaen, Thailand (1970-1986)

Species	Annual Landings																
	1970	1971	1977	1973	1974	1973	1976	1977	1978	1979	1980	1981	1982	1983	1994	1985	1986
Cirrhinus jullieni	71.4	403.6	323.7	171.7	320.4	209.0	358.5	611.4	531.1	547.6	338.1	833.7	348.5	818.0	769.6	319.6	306.9
Puntius gonionotus	16.8	48.1	19.4	46.4	173.8	13.3	28.4	46.0	24.6	25.2	8.9	25.5	9.1	38.7	18.4	18.0	9.5
Puntioplites proctozysron	36.0	38.8	39.9	292.3	503.4	232.6	502.7	353.4	256.7	173.3	142.1	132.7	165.8	32.0	200.8	172.9	247.6
Osteochilus hasselti	80.8	237.9	134.0	126.2	361.8	83.2	132.3	122.3	101.4	60.8	54.6	39.9	29.4	39.2	77.0	69.1	115.6
O. *melanopleura*	23.3	5.7	3.4	0.03	0.82	-	19.9	31.9	53.4	10.9	12.3	20.1	37.6	31.3	31.9	30.7	144.2
Morulius chrysophekadion	70.8	112.5	80.7	176.7	136.5	141.0	136.6	73.2	86.6	27.3	16.2	21.9	46.4	32.0	34.6	26.3	219.4
Hampala spp.	36.1	66.4	43.3	30.7	13.8	11.0	13.0	12.4	20.4	9.8	6.1	7.8	8.1	10.6	13.2	12.1	4.6
Minnows	-	313.1	438.7	419.4	486.2	341.5	480.5	346.6	277.7	271.7	232.8	301.7	281.8	402.8	343.3	248.1	304.3
Total cyprinid landings	299.1	1,426.1	1,083.1	1,263.43	1,994.32	1,035.6	1,871.9	1,599.4	1,373.9	1,126.6	831.1	1,421.3	926.7	1,424.6	1,490.8	917.0	1,332.3
Total annual landing	1,550.8	2,163.8	1,714.8	1,970.4	2,477.3	1,478.2	2,521.3	2,236.9	1,864.8	1,490.0	1,306.0	1,981.0	1,482.2	2,193.2	1,892.2	1,186.4	1,679.1
Cyprinid percentage in total landings	19.29	63.83	63.16	64.12	80.50	70.06	74.24	71.30	73.67	73.61	63.64	71.75	62.52	64.95	78.79	77.73	80.34

Source: The Ubolratana Reservoir Fisheries Development Station

It is difficult to evaluate the value of stocked carps in the landing due mainly to the inability to identify them in the catch at landing places. However, available data on the composition of cyprinids in the landings from capture fisheries in lakes and reservoirs in 1984-1985, will give us an idea of how important the cyprinids are. In 1984 cyprinids comprised 17 575 t in the catch (38.20% of all species landed), and in 1985 16 243 t (32.97% of all species landed). The value of landed cyprinids was 312.41 million baht (30.97% of total landing value) and 321.65 million baht (29.39% of total landing value) respectively (Table 1).

Cyprinids are accepted as food fish in Thailand regardless of their size and species, but with a different degree of preference. Several species such as Probarbus jullieni, Tor tambroides and Cyclocheilichthys enoplos, are highly esteemed as food and command high price in the local market, exceeding 100 baht/kg. The price of most carps range between 20-30 baht/kg, and the price of minnows in the neighbourhood of 10 baht/kg. Cyprinids are usually preferred fresh, but preserved products such as sundried, smoked and fermented forms are also accepted.

4. CONCLUSIONS

Cyprinids are common in Thailand. Most of them are local species, and only a few were introduced from neighbouring Asian countries. Carps have been stocked in lakes and reservoirs since early 1950. During the last 10 years the average number of stocked carps was 42 232 700 fish/yr or approximately 61.38% of all fish stocked. The average cost of carp fingerling production for stocking is estimated at 2.96 million baht/yr. Carps significantly contribute to annual catches both in quantity and value, but it is difficult to evaluate the economic return of stocked carps from landings as we are still unable to separate them from those recruited from natural cyprinid populations. Carps are popular in earthen pond culture in Thailand, but rarely raised in cages and pens. The culture of carps has been increasing continuously since 1977, and in 1986 pond aquaculture produced 13 280 t worth 243.69 million baht.

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SUMMARY REVIEW OF COMMON CARP, CYPRINUS CARPIO L., IN PAPUA NEW GUINEA

by

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Common carp, Cyprinus carpio, were brought to Papua New Guinea (PNG) for aquaculture in village based subsistence fish ponds in highland regions. The intention waa to use this species for this purpose in preference to tilapia (Oreochromis mossambicus) which had failed to be productive in aquaculture due to its reported stunting and low production in ponds. Carp were brought from Singapore, Sydney (Australia) and Irian Jaya (Indonesia) in 1959 and the early sixties (West and Glucksman, 1976). Three varieties were introduced: golden, Cantoneae and mirror. Mirror common carp were reported to have died out (West and Glucksman, 1976) although some interbreeding has occurred and the occasional "mirror variety" common carp can still be seen. It would appear that present stocks comprise a mixture of the original strains.

A modest carp breeding station was established at Aiyura (Eastern Highlands Province) with the intention of distributing carp to villages in the highlands. By the mid-seventies the carp project was considered a "failure" (Haines, 1978; Uwate, 1984). However, in 1983, the carp project was restarted at Aiyura following reports by Paton (1982) and Sagom and Paton (1982). Common carp in aquaculture have contributed very little to fish production in PNG. The major problems have not been with the fish itself but with the aptitude of local people. PNG has no history of aquaculture and attempts to develop this activity have generally failed due to socio-economic factors.

In contrast to the poor production through aquaculture, common carp have been quite successful in colonising natural water bodies in PNG. From Aiyura, carp were distributed throughout PNG with little control over their ultimate destination. In addition, it can be assumed that carp have been "escaping" from aquaculture situations since their first importation. Carp are now reported to occur as feral stocks over a wide range of habitats and regions of PNG. The most information on feral stocks is available for the Sepik River system. The Sepik River fishery has been subject to the most attention within inland areas of PNG. The first record of a carp from this river system was in 1979 (Makis, 1982) and it was clear that carp had entered lowland sections of a Sepik River tributary from the highlands catchment. The spread and potential effects of carp in the Sepik River up until 1984 were reported by Coates (1984). At that time, carp were only beginning to appear occasionally in the major fishing areas for which data were available.

Monitoring of the spread and impact of carp in the Sepik River is continuing under FAO/UNDP project PNG/85/001 (Sepik River Fish Stock Enhancement Project). An interesting situation exists in that quantitative fisheries data exist for three years prior to the appearance of carp (Coates, 1986). A full analysis of the situation has yet to be undertaken, but some general and preliminary observations can be reported. In the last two years (1987/1988) carp have become a common feature of fish landings from floodplain area. Landings are seasonal but are presently estimated to be around 25% of total landings. Based on rough calculations of present catches and the data of Coates (1985 - prior to the appearance of carp), yield of carp from the floodplains will presently be in the region of 1 000 t/yr^{-1} (25%) and likely to increase as the species spreads further and biomass increases.

The most productive habitats for common carp appear to be quieter shallow waters within the river system. It is becoming particularly abundant on and near floodplain areas and in the shallow sections of floodplain lakes. Colonisation of new areas is rapid with significant populations appearing within three to four years. Data on growth rates have not yet been analysed but 5.0+ kg carp are not infrequently seen within two years in recently colonised areas. Fish between 0.75 and 2.0 kg are frequently landed from many areas.

The impact of carp on the Sepik fishery must be viewed with respect to the naturally impoverished native fish fauna (Coates, 1987) and the naturally low fisheries yield of the river system (Coates, 1985). The most important species presently is the introduced tilapia which accounts for about 50% of the yield. Indications are that carp will be a second successful inadvertent introduction, boosting catches in a similar fashion to tilapia.

The potential ecological impact of carp on the native fish fauna and the exotic tilapia were discussed by Coates (1984). That study needs to be updated in the light of more recent data. It is apparent, however, that the habits of carp are quite different to those of the native fishes or tilapia. Coates (1984) concluded that the positive benefits of carp, by increasing fish production, outweighed any known adverse effects at that time. More recent data indicate that common carp have had a significant beneficial impact on the capture fishery.

In conclusion, common carp have been an inadvertent introduction into natural river systems in PNG. The success of this species in aquaculture within PNG has been limited by socio-economic factors. Feral populations, however, have produced valuable resource that is being exploited by the capture fishery in rivers and associated water bodies, complementing the fishery for tilapia and native species.

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PART TWO

Country Reports

CONTENTS

	Page
1. Recent developments in inland fisheries of China, by Tong He-Yi	157
2. Recent developments in inland fisheries of Nepal, by B.P. Sharma	164
3. The status of freshwater capture fisheries in Sri Lanka, by A.M. Jayasekara	169

RECENT DEVELOPMENTS IN INLAND FISHERIES OF CHINA

by

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1. INTRODUCTION

In China there are about 20 million ha of inland waters which can be used for inland fisheries (Liu, 1983). Development of inland fisheries has been rapid during the recent years and this has resulted in a significant increase in fish yield. In 1987, the total freshwater fish yield was 4.071 million tons, which represented 42.6% of the country's total yield of aquatic products. Inland aquaculture produced 3.484 million tons which represented 85.6% of the freshwater yield. The yield of inland capture fishery was thus 0.587 million tons, representing 14.4% of the freshwater fish yield. Table 1 compares yields for the 1950-1987 period.

Table 1

The total and inland fish yields of China
(in million tons)

Year	Inland culture yield	Inland capture yield	Total inland fisheries yield	Total yield from all fisheries
1950	0.066	0.300	0.366	0.912
1955	0.319	0.543	0.862	2.518
1960	0.500	0.668	1.168	3.038
1965	0.514	0.456	0.970	2.984
1970	0.582	0.312	0.904	3.185
1975	0.753	0.312	1.065	4.412
1977	0.768	0.308	1.076	4.695
1980	0.902	0.338	1.240	4.497
1985	2.379	0.475	2.854	7.052
1986	2.952	0.530	3.482	8.224
1987	3.484	0.587	4.071	9.550

Inland waters of China harbour 766 fish species and subspecies which belong to 23 orders, 52 families. Among these there are 694 freshwater species, 55 brackish species and 17 migratory species, 417 species or subspecies are cyprinids. Carps, mostly the warmwater species, dominate in China's aquaculture. The major cyprinids in order of their importance in aquaculture are: silver carp (*Hypophthalmichthys molitrix*), grass carp (*Ctenopharyngodon idella*), bighead carp (*Aristichthys nobilis*), common carp (*Cyprinus carpio*), mud carp (*Cirrhinus molitorella*), blunt snout bream (*Megalobrama amblycephala*), crucian carp (*Carassius auratus*) and black carp or snail carp (*Mylopharyngodon piceus*) (Bardach *et al.*, 1972, Zhong, 1980).

2. FISHERIES DEVELOPMENT

The following measures have been introduced to enhance inland fisheries in China:

(a) Activities of the national, cooperative and individual fish farmers in developing inland fisheries are being encouraged. A new fisheries law has been put into practice with the purpose of stabilizing the fish production.

(b) Production of fry and fingerlings for aquaculture purposes is rising. At present about 1 200 hatcheries produce 1 385 hundred million fry per annum, with wide application of induced spawning of carps using HCG and LRH-A. 1 227 hundred million fry per year of carps are being produced in this way. About 156 hundred million fry, mostly cyprinids, are still collected from the open waters of the Changjiang (Yantze River) upstream of Nanjing, and from the Zhujiang (Pearl River). More than 300 hundred million fingerlings are being reared each year. The proportion of big size fingerlings in the total of the seed produced is gradually increasing.

(c) Application of fish feed and water fertilization is common. Fish pellets are made from by-products of grains, oil seeds, meat processing industries. Some species of aquatic plants such as Wolffia arrhiza, Lemna trisulca, Spirodela polyrhiza, Vallisneria spiralis, Hydrilla verticillata have been harvested or cultured for their use as fish feed. Highly productive grass of high quality is being planted near fish ponds to be used as fish feed when there is shortage of other types of feed such as aquatic plants. Such grasses include the following: Medicago sativa, Sorghum sudanense, Lactuca denticulata, Lolium pereme, Pennisetum purpureum. Organic manure and inorganic fertilizers are used in ponds, small lakes, and in small coves of reservoirs for encouraging plankton and benthos production.

Other measures for enhancement of inland fisheries include new ponds, provision of new equipment and fish processing machinery, training, assistance in research, and fisheries management and marketing.

3. PRESENT STATUS OF CHINA'S INLAND FISHERIES

3.1 Pond fish culture

The freshwater pond fish culture has been growing fast. The cultured area has increased from 821 513 ha in 1980 to 1 394 400 ha in 1987, and in 1987 the yield was 4.2 times that of 1980 (Tan et al., 1987, Tong et al., 1987). In 1987 the fish yield from ponds represented 64.3% of the total yield of inland fisheries, or 75.1% of the yield of the inland culture fisheries (Table 2). The major cultured species were silver, grass, bighead, common and crucian carp, blunt snout bream and mud carp. In the south of China the grass carp is the key species in polyculture. In the north the common carp or the grass carp are the key species in polyculture. A number of exotic species have been polycultured in ponds and played an important role in increasing the pond culture yield (Tan and Tong, 1989). High yield pond fish culture was thoroughly tested in Zhujiang and Changjiang river deltas, and in suburbs of Shanghai and Beijing. The experience gained has been popularized in many places of China. However, the present major constraint is the shortage of feed.

Table 2

Cultured areas and yields from pond fish culture for the 1980-87 period

Year	Cultured areas (ha)	Total yield (tons)	Average yield (kg/ha)
1980	821 513	620 528	755.3
1981	847 620	718 961	848.2
1982	918 800	870 948	947.9
1983	964 927	1 030 775	1 068.2
1984	1 070 633	1 322 082	1 234.8
1985	1 257 600	1 749 364	1 391.0
1986	1 335 733	2 193 795	1 642.4
1987	1 394 400	2 617 978	1 877.5

3.2 Lake fish culture

The major species in lake fish culture are silver carp and bighead carp which feed on plankton snd detritus. In polyculture systems common carp, blunt snout bream, crucian carp and grass crap are added. Fingerlings of many fish species, macrops of mitten crab Eriocheir sinensis and elvers of Anguilla japonica are also stocked. To prevent fish from escaping, screens made of bamboo or nets are set at inlets and outlets of lakes. In 1987, lake fish culture covered 645 953 ha, with a yield of 207 814 tons (Table 3).

Table 3

Cultured areas and yields from lake fish culture for the 1980-87 period

Year	Cultured areas (hs)	Total yield (tons)	Average yield (kg/ha)
1980	538 833	73 881	137.1
1981	492 560	67 568	137.1
1982	576 013	77 329	134.2
1983	556 907	91 068	163.5
1984	537 040	104 602	194.8
1985	622 687	143 741	230.8
1986	657 953	178 669	271.6
1987	645 953	207 814	321.7

3.3 Reservoir fish culture

Large-scale development of China's reservoir fish culture started in the 1960s (Lu, 1986, Li, 1988). The principal species cultured in reservoirs are silver carp and bighead carp which utilize plankton and detritus, the dominant natural food resources. Good management requires to stock optimum sized fingerlings, control of predators and low value fish species by intensive fishing, and installation of nets or electric screens at spillways to prevent fish escape. Elopichthys bambusa, Erythroculter ilishaeformis, Erythroculter mongolicus, Silurus asotus, Siniperca chuatsi, Channa argus, Perca fluviatilis, Esox spp., Opsariichthys spp. are the main predatory fish species in China's reservoirs. Hemiculter leucisculus, Pseudolaubuca sinensis, Pseudorasbora parva are common low value fish in Chinese reservoirs. Combined fishing methods including block nets, trammel nets, seine nets, large set nets are commonly applied. The cultured area and the yield of China's reservoir fish culture was 1 429 700 ha and 278 572 t in 1987 respectively (Table 4). Cage fish culture has been applied in reservoirs for many years. Cage culture is also practised in lakes and rivers where the water level is deep enough. In 1987, the area of cage culture reached 380 ha. The coldwater outflow from large reservoirs is utilized for culture of rainbow trout, even in southern parts of China, e.g. Xinanjiang Reservoir of the Zhejiang Province.

Table 4

Cultured areas and yields from reservoir fish culture for the 1980-87 period

Year	Cultured areas (ha)	Total yield (tons)	Average yield (kg/ha)
1980	1 266 660	111 966	88.4
1981	1 281 133	118 705	92.7
1982	1 298 753	113 424	87.3
1983	1 298 287	149 522	115.2
1984	1 334 540	175 586	131.6
1985	1 375 667	206 434	150.1
1986	1 402 067	236 076	168.4
1987	1 429 700	278 572	194.8

3.4 River fish culture

The rivers are important for fish culture especially in Zhejiang, Jiangsu and Fujian provinces. In 1987, river fish culture was practised on 324 887 ha, including irrigation canals. The traditional method of river fish culture is to set screens, made from bamboo or nets, at both ends of a river in order to prevent fish escape. There are boat passing facilities on such rivers which allow the boats to pass through the screens. The fingerlings of silver, bighead, grass and crucian carp, blunt snout bream are stocked between such screens. The fish feed on the natural food. Fish cages are also placed in the river current where dissolved oxygen concentration is high enough to culture grass carp or common carp. Freshwater shrimp Macrobrachium nipponense is also kept in cages. In 1987, the yield from river fish culture reached 219 741 t (Table 5).

Table 5

Cultured areas and yields from river fish culture for the period 1980-87 period

Year	Cultured areas (ha)	Total yield (tons)	Average yield (kg/ha)
1980	247 140	82 154	332.4
1981	258 947	87 010	336.0
1982	253 647	92 343	360.1
1983	251 180	102 784	409.2
1984	281 300	129 023	458.7
1985	310 287	161 250	519.7
1986	328 273	197 685	602.2
1987	324 887	219 741	676.4

3.5 Inland capture fishery

The inland capture fishery has been limited by several factors. The capture area has been gradually decreasing as a result of introducing aquaculture in aome lakes, reservoirs and rivers. Engineering structures for river regulations have been constructed on and along the Changjiang and its tributaries, and this has resulted in a lower fish production. As a result of such structures the already migrating route of many species of fishes were cut off 20 to 30 years ago. Polluted waters from industries and agriculture are discharged into rivers and lakes, often causing fish mortalities. In some situations, breeding fish and young fish are captured indiscriminately using illegal fishing gear and fiahing methods. Overfishing depletes fish stocks and affects the recruitment.

Some conservation measures to protect fishery resources are being applied. Conservation regions and periods closed to fishing have been established to allow fish to spawn, and the young fish to grow to a mature stage. Fingerlings of some species are being released to enhance fish stocks. Standards for water quality for fisheries were established and the water quality is now monitored by the Bureau of Environmental Protection. The Bureau controls the treatment of waste water and sewage disposal in factories in order to keep the water quality aa high as possible. Several low waterhead fishpasses have been constructed at the engineering structures along the Changjiang to improve the migrations of fish. The Chinese sturgeon (Acipenser sinensis) is induced-spawned and sturgeon fingerlings are released from hatcheries into the Changjiang every year to replenish the stocks. However, the aturgeon, as well as Reeves shad (Macrura reevesii) which is also anadromous, require strict protection and management of their stocks are to be maintained at a healthy level (Shanghai Fisheries University, 1988).

3.6 Fish introductions

For many years exotic fish have been introduced into inland waters of China, and by now a number of exotic species contribute to fisheries (Tan and Tong, 1989). There has also been a number of transfers within the country.

Mozambique tilapia (*Oreochromis mossambicus*) was introduced in 1957 and polycultured with Chinese carps in ponds for about 20 years. It is not an attractive species in China due to its slow growth and small size and it receives a low preference from consumers. It is being replaced by Nile tilapia (*Oreochromis niloticus*) which was introduced in 1978. The hybrid of *O. mossambicus* and *O. niloticus* is considered as an important fish in polyculture with Chinese carps. Blue tilapia (*Oreochromis aureus*) was introduced in 1981 in order to produce 90% male offsprings (F1) through hybridization with *O. niloticus*. Tilapias are used in pond fish culture, running warmwater fish culture, cage fish culture and integrated aquaculture. With the exception of Hainan, tilapias cannot overwinter in natural waters due to low water temperature. They need to be moved to greenhouses or into heated waters.

Silver crucian carp (*Carassius auratus cuvieri*), indigenous to Lake Biwa of Japan, was introduced in China in 1976 and after 2-3 years trial quickly popularized in many provinces because the subspecies has fast growth, reaches large size, easily adapted to new environment, is easy to catch and is resistant to diseases. Breeding and seed production are similar to that of the local crucian carp (*Carassius auratus auratus*). It is now widely cultured in China, particularly in the Changjiang Basin.

Rainbow trout (*Salmo gairdneri*) was introduced in 1959. It is cultured in [illegible] provinces and autonomous regions, in concrete pools of a rectangular or circular shape or in cages placed in lakes, reservoirs and streams. As China has many cold waters there is a great potential to further expand the rainbow trout culture.

There have been some good results of the fish transfer within the country. *Neosalanx taihuensis* (Salmoniformes, Salangidae) is a small size warmwater plankton feeder with short life span. Its fertilized eggs were transported from Lake Taihu of Jiangsu Province into Lake Dianchi and Lake Xingyun of Yunnan Province. After repeating the transfer for 2-3 years, the fish populations became established in both lakes. Lake Dianchi, a mountain eutrophic lake of 30 000 ha, is situated 1 887 m above sea level. It has an average depth of 5 m, maximum and minimum water temperature 20.1°C and 9.2°C respectively, and is rich in plankton. The fertilized eggs were transported from Lake Taihu during 1979-1981 and after hatching the larvae were released into the lake. In 1983, 2 000 t were caught, 2 200 t in 1986, 3 200 t in 1987. In Lake Taihu, 2 500 t were caught in 1986, but the area of Lake Taihu is seven times that of Lake Dianchi. Lake Xingyun is an eutrophic lake with an area of 3 467 ha. It is situated at an altitude of 1 722 m above sea level, and has an average depth of 7 m. The average water temperature is 20°C in summer, 10°C in winter. *Neosalanx taihuensis* was transported in 1982 from Lake Taihu, and the catches reached 78 t in 1985 and 200 t in 1986.

In conclusion, it should be said that in spite of much progress in inland fisheries, there is still much to be done. In China, the average supply of freshwater fish/person/yr is still less than 4 kg out of the total fish consumption of 8.84 kg/person/yr. The main developmental potential is seen in the inland fisheries, particularly in aquaculture.

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RECENT DEVELOPMENTS IN INLAND FISHERIES OF NEPAL

by

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1. INTRODUCTION

Fish is relished by all strata of the Nepalese people and also considered as a token of good luck (shagun). Although fish culture has a short history in Nepal, capture fisheries in traditional ways has been practised since the old days (Anon., 1967).

From 1947, fish culture was started on a small scale by importing Indian Major carp fingerlings from India. Later on, common carp was introduced in Nepal from India and Israel in 1956 and 1960-61 respectively. Grass carp and silver carp were imported in 1967 and 1969, and bighead carp in 1971-72 from India, Japan and Hungary respectively (Rajbanshi, 1980).

Although the proportion of fish to the total animal protein intake is very low (600 gm per caput), fish is acceptable to every segment of the population. Thus, in the country the demand for fish is very high and is mostly met by domestic production. The rest is imported from neighbouring countries. The domestic production comes from traditional capture fisheries in the natural waters, as well as from the steadily increasing pond and lake aquaculture.

Being an integral part of agriculture the fisheries development programme cannot be overlooked in the overall development of agriculture as this sub-sector provides (a) the supplementary source of high valued protein at lower cost, (b) potential for employment and income generation, and (c) helps in part a more ecologically balanced use of land and water resources.

2. FISHERIES RESOURCES

2.1 Inland water resources

In land-locked Nepal production of fish is entirely dependent on the proper utilization of its inland water resources. Significant fish production can be achieved through the development and management of culture and capture fisheries practices.

The inland water resources of Nepal consist of three major river systems, i.e. Kosi, Gandaki and Karnali, and of several small rivers originating from Mahabharat snd Siwalik ranges. A number of small as well as medium sized lakes, with a total area of 5 000 ha, are scattered throughout the country. Besides these natural water bodies, about 5 000 ha of villsge tanks and ponds are mostly located in the southern plains called terai. Additional 325 000 ha of irrigated paddy fields and 1 500 ha of man-made reservoirs also exist in the country.

Hydropower and irrigation projects will add more water bodies in the future: the Gandaki basin, 45 000 ha (Prosser, 1978), Bagmati River System, 9 000 ha (Shrestha *et al.*,1979) and Karnali River System, 24 000 ha (Nippon Koei, 1966), might add about 78 000 ha of reservoirs upon completion. Further 1 400 ha of new fish ponds are planned during the second Aquaculture Development Project.

Having in mind the country's existing water resources (Table 1) and their further potential, there is a great scope for expansion as well as for intensification of fish production.

Table 1

Estimated water surface area in Nepal
(APROSC, 1986)

Types of water resource	Present area (ha)	Planned expansion (ha)
Rivers	395 000	-
Lakes	5 000	-
Reservoirs	1 500	78 000
Village ponds	5 000	1 400
Irrigated paddy fields	325 000	-

2.2 Fish species

The recently published general bibliography of fish and fisheries of Nepal shows a total of 171 indigenous fish species distributed in various river systems and water bodies between the terai and 4 000 m altitude (Rajbanshi, 1982; Shrestha, 1981). Terashima (1984) has reported three new species of *Schizothorax* spp. which makes a total of 174 species. Besides the indigenous fish species, seven exotic fish species of commercial value were also introduced in the country, of which three cold water species: *Salmo gairdneri*, *Salmo trutta* and *Oncorhynchus rhodurus* do not exist presently (Rajbanshi, 1982). The rest, i.e. four commercially highly valued warmwater fish species: common carp (*Cyprinus carpio*); grass carp (*Ctenopharyngodon idella*); silver carp (*Hypophthalmichthys molitrix*), and bighead carp (*Aristichthys nobilis*) are being cultured along with three highly valued indigenous fish species, i.e. rohu (*Labeo rohita*); catla (*Catla catla*) and mrigal (*Cirrhinus mrigala*). Efforts are being made for commercial production of three highly valued cold water fish species: asala - *Schizothorax* spp., katle - *Acrossocheilus hexagonolepis* and mahaseer - *Tor* spp.

2.3 Capture fishery management

Until recently, little emphasis has been given to the fisheries management for increased fish production in rivers, lakes and reservoirs. The capture fishery is widely scattered and poorly organized. Fishermen living along the rives and lakes use their traditional fishing gear largely for subsistence fishery with nominal economic benefits. To improve capture fisheries management, especially in cold waters, experiments have been initiated to induce breeding of some indigenous cold water fish species, e.g. asala, katle and mahaseer, and to propagate them on a mass scale for stocking of open waters. Only with a proper fishery management the potential of rivers and high altitude lakes can be realized. His Majesty's Government of Nepal has accorded high priority to this task and has established a fisheries development centre for riverine fisheries development in Trisuli.

In Nepal, cage fish culture of planktivorous fish is now well established and economically viable in the lakes of Pokhara Valley (Pradhan and Shrestha, 1979; Sharma, 1979). Since 1978, private fish growers have undertaken cage fish culture in Pokhara Valley and the total volume of cages has reached about 20 000 m^3. Production of 4-5 kg/m^3 has been found to be economically viable in the lakes of Pokhara Valley. Realizing the growing popularity of cage fish culture practices in natural water bodies, His Majesty's Government of Nepal, with the technical assistance from IDRC, Canada, has supported a study project on the Indrasarowar Hydroelectric Reservoir at Kulekhani, the objective of which is to test the suitability of the reservoir waters for cage culture and for enhancing fish production from open waters through regular stocking. This should lead to an improvement in the living standard of local fishermen.

2.4 Fish production

Fish is produced mainly by the private sector. There exist several development programmes which are supported by the Government. Fisheries statistics show that a total of 12 800 t of fish was produced in 1987-88, out of which 5 281 t is contributed by capture fisheries, and from this about 85% constitute indigenous fish species.

2.5 Development constraints

Some of the major constraints of a rapid development of inland fisheries are diagnosed as follows:

- lack of base-line studies on limnology, fish stocks and fisheries of natural waters, i.e. rivers, lakes and reservoirs;
- shortage of trained and experienced manpower in the field of fish production and extension services for follow-up action;
- lack of knowledge of the production potential of indigenous fish species;
- inadequate infrastructures in production oriented research; and
- inadequate financial resources for production expansion.

2.6 Development opportunities

There is a substantial scope for fisheries development as Nepal is rich in fresh water resources. Potential for increased fish production exists through an expansion of fisheries as well as through the intensification of fisheries management practices. Fish production could be increased through:

- standardisation of nursing and rearing techniques, increase in fish seed production as well as determination of appropriate stocking rates and optimal size of fingerlings;
- combination of one or more indigenous fish species in culture and capture fisheries, based on the knowledge of their biology and production potential;
- construction of new ponds for expansion of fish culture;
- development, expansion and intensification of cage fish culture in lakes and man-made reservoirs of the mid-hills and careful monitoring of the results as well as of the limnological factors closely related to fish production;
- development of aquaculture in paddy fields.

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THE STATUS OF FRESHWATER CAPTURE FISHERIES IN SRI LANKA

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1. INTRODUCTION

There are about 140 000 ha of freshwater irrigation reservoirs (tanks) in Sri Lanka. Most of these have been built in ancient times. The old reservoirs have been constructed 2 500 years ago. Arumugam (1969) gives an account of the development of the reservoir systems in the country. The principle purposes of the construction of reservoirs have been irrigation and, more recently, hydroelectricity production. The reservoirs in Sri Lanka are often categorized into major, medium and minor, although functionally they can be divided into perennial and seasonal. The number of irrigation reservoirs is estimated to be over 10 000 (Abewickrama, 1955). Several new reservoirs serve for both irrigation and generation of hydroelectric power. Water level declines during the drought as the water is drawn for irrigation. The size varies from a few hectares to more than 7 000 ha, with the largest one, Senanayake Samudra, of 7 800 ha. It is estimated that 2.5 - 3% of Sri Lanka is covered by impounded freshwaters.

Irrigation tanks and irrigation/hydroelectric reservoirs represent the major freshwater resource for capture fishery. The capture fishery acquired economic importance after the introduction of tilapia and establishment of their breeding populations in large irrigation tanks. The present annual fish production from reservoirs is about 36 000 t and contributes some 18% of the total fish production in the country. The fishery largely depends on O. mossambicus constituting 60 to 70% of the catch.

The type of crafts operated are either fibre glass or dugout canoes, or log-crafts which are operated by two persons. Mechanized boats are not used in the reservoirs of Sri Lanka. The fishing gear are mainly gill nets, with mesh size ranging from 76 to 140 mm. Occasionally cast nets, hook and line fishing is applied, but they do not contribute significantly to the fishery. As the bottom of the reservoirs is uneven, this feature, along with the presence of obstacles such as tree trunks, obstruct the use of bottom gear. Thus, the reservoir fishery is essentially restricted to the use of gill nets (De Silva, 1983; 1985).

The Government of Sri Lanka has launched several programmes to stock the reservoirs with suitable species of fish, introduce legislation to control fishing, increase harvesting efforts by introducing fibre glass canoes instead of wooden dugouts and to set up Fisheries Social Development Societies (FSDS) for the welfare of the fishermen. It is plannned to increase the total inland fish production to 55 000 t by 1990.

2. CAPTURE FISHERY RESOURCES

Mendis (1977), Sreenivasan (1982) and Thayaparan (1982) summarised the estimates of the extent of reservoirs. They estimated that there are 139 271 ha of freshwater bodies, and these were classified by Sreenivasan and Thayaparan (1983) as follows:

Category	No.	Extent (ha)	Potential annual fish production (t)
Major irrigation reservoirs	73	70 850	26 000
Medium tanks	160	17 004	
Minor irrigation tanks	3 279	39 271	13 000
Villus (floodplains)		4 049	450
Upland reservoirs		8 097	450
Total		139 271	39 900

Jayasekara (1987) estimated that there are 212 000 ha of freshwater bodies in Sri Lanka. This includes 100 000 ha of seasonal tanks estimated by Thayaparan (1982). Unpublished recent estimates give 272 223 ha of reservoirs in the country. This area will be increased by 22 670 ha with the completion of the Mahaweli Diversion Scheme. The potential annual fish production from these water bodies has been estimated 45 000 t.

The number of tanks in Sri Lanka in the individual size groups was summarised by Oglesby (1981) as follows:

Size Group	Number
10 000 - 19 999 acres (4 050 - 9 100 ha)	1
1 000 - 9 000 acres (405 - 4 000 ha)	47
100 - 999 acres (40.5 - 400 ha)	182

The total area of 230 tanks is 87 720 ha. There are also several thousand tanks in the range of 4 - 40.5 ha.

According to De Silva (1985) there are only 11 reservoirs, the surface area of which exceeds 2 000 ha. This will increase to 17 on the completion of the Mahaweli Diversion Scheme. The total extent of perennial reservoirs over 250 ha of surface area has been estimated to be around 126 000 ha.

3. FISH FAUNA

There are 59 species of fish found in the fresh waters of Sri Lanka (Munro, 1955; Fernando and Indraaena, 1969; Fernando, 1973). At least 20 of the freshwater fish species are valued as food fish (Indrasena, 1965; Fernando and Indrasena, 1969; TAMS, 1980). Since the introduction of Salmo trutta in 1882, eighteen exotic species have been introduced into the country (De Silva, 1983; Chandrasoma, 1983). However, only thirteen species have been established either as naturally breeding populations or economically important species. These are Cyprinus carpio, Carassius carassius, Oreochromis mossambicus, Oreochromis niloticus, Tilapia rendalli, Osphronemus gouramy, Ctenopharyngodon idella, Aristichthys nobilis, Hypophthalmichthys molitrix, Catla catla, Labeo rohita, Cirrhinus mrigala and Salmo gairdneri. Although records indicate that two Chinese major carps (Ctenopharyngodon idella, Hypophthalmichthys molitrix) and one Indian major carp (Catla catla), were introduced in 1942 and 1948 respectively, no attempts have been made to breed them artificially. These species were reintroduced by the Ministry of Fisheries in 1975, 1981 and 1982 respectively from China and India and they were successfully induced bred at the government hatcheries.

4. FLOODPLAIN LAKES - VILLUS

There are no natural lakes in Sri Lanka. The villus or floodplain lakes are vegetated land areas inundated with water seasonally and retaining their connection to the rivers most of the year. A villu consists of a ponding area which is permanently filled with water, and a floodplain which is inundated by water during the flood period.

Hunting Survey Corporation (1962) reported 40 000 ha of floodplain lakes, of which 16 000 ha are reported in the Mahaweli Basin. According to TAMS (1980) there are 50 distinct villus with a total area of 12 800 ha. The largest three range in area from 400 to 900 ha.

Villus serve as habitats for a number of indigenous fish apecies, amphibiana, birds and as grazing ground for livestock. The villus are also breeding grounds for many other riverine fishes such as Labeo dussumieri and nursery grounds or feeding grounds of various species (Welcomme, 1979). O. mossambicus, Tor khudree, Labeo dussumieri and Puntius sarana are fish caught in villus. The freshwater prawn Macrobrachium is also fished there. Indrasena (1965, 1970) gave an average annual yield for the Mahaweli Ganga floodplains as 35 kg/ha, Welcomme (1979) suggested 300-1 000 kg/ha, and De Silva (1985) estimated 150 kg/ha. Thayaparan (1982) is of the view that villu fiahery is on the decline due to diversion of rivers, construction of flood protection achemes and increased wildlife conservation.

5. RESERVOIRS IN THE MAHAWELI SYSTEM

Under the Accelerated Mahaweli Development Programme which is the largest river basin development project in Sri Lanka, 22 670 ha of new reservoirs will be added to the existing area (Thayaparan, 1982). The five large reservoirs constructed under the project are Maduru Oya (6 280 ha), Randenigala (2 750 ha), Ulhitiya (2 270 ha), Victoria (2 270 ha) and Kotmale (970 ha).

Kotmale reservoir is at the top of the system from which water is conveyed to Victoria reservoir through Polgolla. Water leads to Randenigala from Victoria and flows to Ulhitiya via the Minipe diversion scheme and into Ratkinda. Maduru Oya is supplied by a tunnel from Ratkinda. The total dissolved salts and nutrients increase from Kotmale to Maduru Oya. Reservoirs other than Kotmale, Randenigala and Victoria are expected to be moderate to highly productive (Sreenivasan and Thayaparan, 1983).

Mahaweli reservoirs need to be stocked as there are no indigenous species of commercial value in them. Sreenivasan (1982) suggested stocking several species as the new Mahaweli reservoirs are quite deep and cannot be compared with shallow reservoirs like Parakrama Samudra (2 262 ha; 9.7 m) where *O. mossambicus* highly dominates.

Maduru Oya (6 280 ha) is the second largest reservoir in Sri Lanka. Other important older reservoirs in the system are Pimburattewa (1 073 ha), Aralaganwila and Vakkaneri. The total fish yeild for all the reservoirs in the system is estimated to be 2 000 t (Sreenivasan and Thayaparan, 1983). There are about 5 600 ha of large and medium water bodies which are expected to yield about 1 350 t of fish when fully developed. The large and medium tanks and village tanks account for 7 816 ha. A production of 2 360 t from these water bodies has been estimated by Sreenivasan and Thayaparan (1983).

De Silva (1985) has estimated the present total yield from reservoir fishery of the Mahaweli Basin as 3 000 t averaging a yield of 375 kg/ha/yr based on 1980 production data.

O. mossambicus dominates in the fish catches of Mahaweli reservoirs. Two cyprinids, *L. dussumieri* and *P. sarana*, contribute significantly to the commercial catches. Two carnivorous indigenous species *Wallago* and *Channa* are also important constituents of catches though few in number. De Silva (1985) observed that the composition of *P. sarana* and *L. dussumieri* in the catch has been on the decrease since 1976. The landing size of *O. mossambicus* has decreased. He also reported the appearance of *Hyporamphus gaimardi* in all the major reservoirs in Mahaweli Basin, and development of a small fishery for this species.

The small indigenous species *Puntius dorsalis*, *P. filamentosus*, *P. chola*, *Danio equipinnatus*, *Amblypharyngodon melattinus* and indigenous carnivores remain unexploited. A possible yield of 20 - 50 kg/ha/yr of minor carps and 10 - 25 kg/ha/yr of carnivores has been suggested. Management measures could be effectively introduced to tap these resources without harming the existing fishery (De Silva, 1985).

6. THE FISHERY

O. mossambicus has been the main species stocked in reservoirs since the 1950s. This fish has spread rapidly to almost all the reservoirs and other water bodies. At present the reservoir fishery is dominated by this species. Thus, its introduction in 1952 has been instrumental in the establishment of reservoir fishery in Sri Lanka. The present contribution of this species to the total catch is as high as 60-70% in many reservoirs and more than 90% in some of the reservoirs.

The success of this species has been attributed to its easy breeding (Fernando and Indrasena, 1969), lack of lacustrine species in the indigenous fauna capable of colonizing such habitats (Fernando, 1965) and the non-catholic nature of its diet (De Silva, 1983). Costa *et al.* (1988) attributed the success of *O. mossambicus* in the man-made reservoirs to the abundance of plankton, the mouth breeding habit of this fish and its ability to shift to available diets.

Chandrasoma (1982) reported the regular appearance of *T. rendalli* in catches of Parakrama Samudra. Chandrasoma and De Silva (1981) mentioned that in some reservoirs this species contributed to the fish catch around 10%. They suggested that in reservoirs, in which the species become established, it is controlled by the limited supply of macrophytes on which the fish feed. In the mid-1980s *T. rendalli* in some reservoirs contributed up to 36.34% to the total catch (Chandrasoma, 1986).

Data from some reservoirs indicate that in 1986 *Sarotherodon niloticus* dominated or was the second fish species after *O. mossambicus* in commercial catches. Records on its percentage in the total catch are available for the following reservoirs: Giritale - 15.56%; Parakrama Samudra - 56.87%; Kalawewa - 15.6%; Soraborawewa - 72.17%; Dambarawa - 37.1%; and Rathkinda - 39.07%. In Nagadeepa reservoir *O. niloticus* has increased from 8% in 1983 to 28.1% in 1986. In Soraborawewa there was a drastic reduction in *O. mossambicus* (Chandrasoma, 1986).

Although common carp was stocked in many reservoirs, its appearance in commercial catches is insignificant. However, in some of the reservoirs in the Northern Province it contributes up to 40% (S. Sambasivam, pers.com.). In the hill country reservoirs this species contributed 2.6% in Castlereigh (363 ha) and 12.3% in Mausekelle (712 ha). However, the major species caught in these reservoirs is *O. mossambicus*. In 1978 the author observed common carp in large numbers in the high altitude Gregory reservoir(30 ha). When the water level was reduced for dredging of the reservoir, the author observed many common carp eggs attached to submerged vegetation throughout the shallow areas. In a few small hill country reservoirs the major species caught is common carp.

Chinese carps have been stocked in the reservoirs since 1978. Between 1978 and 1986, Udawalawe reservoir (3 374 ha), located near the main Chinese carp breeding station, was stocked with about 54 000 fingerlings of grass carp, 147 350 fingerlings of bighead carp, and 13 400 fingerlings of silver carp. But in 1986 Chinese carps contributed only 0.32% to the commercial catch, with tilapias representing 75%. Although the fish were absent from the gill net catches, large size Chinese carps were collected when the sluice gate was opened for irrigation discharges.

Indian major carps have been stocked in the reservoirs since 1983. Only rohu has started appearing in the commercial catches. The contribution of this species to the commercial catch was 43% in Kandalama (794 ha), 15% in Devahuwa (384 ha), and 16% in Giritale, based on the data for 1983 to 1986.

Illukkumbura (1986) mentions the appearance of rohu in the fish catches of Udawalawe (3 374 ha) and Kandalama (794 ha) reservoirs six and eight months after stocking, respectively. In both reservoirs rohu has attained an average weight of over 1 kg within a year. In the second year fish weighing 4 kg have been caught in both reservoirs. In some reservoirs rohu contributes up to 16% to the total catch.

The main indigenous species of fish which contribute to the commercial catch are Puntius sarana, Labeo dussumieri and Etroplus suratensis. The carnivorous species Wallago and Channa also occur in the catches sporadically and in small numbers. L. dussumieri, P. sarana and P. dorsalis are important food fishes. L. dussumieri contributed up to 25% in some reservoirs in 1980. However, the catch of indigenous species in some reservoirs is on the decline. While in 1983 L. dussumieri contributed 40% to the total catch of Nagadeepa wewa (327 ha), it has since then declined. In Castlereigh, Maussakelle and Polgolla reservoirs the catch of L. dussumieri has also decreased over the years. These reservoirs are located in the hill country. Catches from these reservoirs show an increase of tilapias.

As a result of the Mahaweli Diversion Scheme, some of the reservoirs such as Nachchaduwa, Kalawewa and Balaluwewa retain a fluvial character and maintain a high water level for most of the time. The high percentage of L. dussumieri in them can be attributed to this character (Chandrasoma, 1983).

The stocking size of tilapia and common carp is usually 5-6 cm and 4-8 cm respectively. The stocking size of Indian and Chinese carp fingerlings ranges between 5-7 cm. Stocking of reservoirs with large-sized fingerlings has been recommended by the Chinese experts in Sri Lanka. However, it is difficult to stock large-sized fingerlings as there is no adequate pond space in the fisheries stations to rear them to the required size. It may be possible that the size of fish stocked is too small for them to survive in waters where there is a considerable number of predatory fish.

Due to limited pond space for raising of fingerlings, the reservoirs are stocked with only small and probably insufficient number of fingerlings. The gill nets used in reservoirs appear to be selectively catching tilapias, and they may not be suitable for catching carps, especially the common carp which is a bottom dweller.

7. RESERVOIR FISH YIELD

The potential annual fish yield for hill country reservoirs has been given as 56 kg/ha (Mendis, 1965). According to TAMS (1980) the yield from these reservoirs is in the region of 20-35 kg/ha. The lowland reservoirs have a higher production. Mendis (1965) and TAMS (1980) have given figures 112 kg/ha/yr and 100-300 kg/ha/yr, respectively. Oglesby (1981) has given a range of 111-357 kg/ha/yr.

The potential fish yield from villus (floodplain lakes) is 112 kg/ha/yr (Mendis, 1965) or 50 kg/ha (TAMS, 1980). The total fish production from the reservoirs in the Mahaweli system has been estimated 3 539 t/yr (De Silva, 1985).

Oglesby (1981) attempted to broadly characterise the tanks according to their potential yield. He estimated the potential catch by extrapolating the data of a few relatively well studied intensively fished tanks. According to him the annual catch from the large tanks of Sri Lanka is approximately 28 000 t. De Silva (1985a) gives the yield estimate as 283 kg/ha/yr.

8. MANAGEMENT OF RESERVOIR FISHERIES

The reservoir fisheries are regulated by the Inland Fishery Regulations of 1978. Types of fishing gear and the operation, mesh size, etc., are regulated. The number of fishermen permitted to do fishing in a particular reservoir is also controlled. Fiahing in reservoirs coming under the Mahaweli system and wildlife protection areas is controlled under the supervision of corresponding authorities for each area. Beach seines and motorised crafts are not permitted in the inland reservoirs.

De Silva (1985a) stated that a reservoir is considered overexploited when the proportion of undersized fish (less than 20 cm length) present in the reservoir is above 50% and they recommended that the minimum landing size of O. mossambicus should be maintained above 20 cm. They further recommended that the minimum permissible mesh size of gill nets should be 102 mm or 4".

The number of crafts that are introduced into a reservoir is con- trolled by the local fisheries office, depending on broad estimates of fish catches. It has been suggested by Costa et al., (1988) that the average daily yield for one boat using gill nets should be at least 18-20 kg. They recommend to increase the number of boats if the yield is over 25 kg/boat/ day in normal gill net operations. The number of boats that could be introduced to a particular reservoir is derived from the MEI as follows:

Reservoirs with high MEI	(>100), 1 craft per 25 ha
Medium MEI	(50 - 100), 1 craft per 35 ha
Low MEI	(50), 1 craft per 45 ha

To facilitate the fishery management in reservoirs, Fisheries Social Development Societies (FSDS) have been organized by the Ministry of Fisheries (MOF). The members of FSDS are fishermen. The subsidy boats are issued to the members of the FSDS only. In some reservoirs the Society determines the mesh size of gill nets to be used. Fishermen from coastal areas migrate to inland reservoirs during off season. Most of the inland fishermen who are inexperienced in fishing learn to use the fishing gear from these migratory fishermen, although at times conflicts arise between the migratory fishermen and local fishermen. About 50 000 persons are engaged in the inland capture fishery.

9. CLEARING OF SUBMERGED TREES; AQUATIC WEEDS

Reservoirs of Sri Lanka are characterised by the presence of tree stumps which is considered a hazard for fishing crafts and fishing nets. Sreenivasan (1982) reviewed the various opinions expressed on the subject of clearance of submerged trees. TAMS (1980) recommended bush clearing in Mahaweli system before reservoir flooding. Bhukaswan (1980) stated that it is advantageous not to clear 20-25% of the reservoir bed because such areas would serve as shelters from predators and as additional food source and breeding areas for many fish species.

Suggestions for partial clearing of trees in reservoir beds in the Mahaweli system had been made, but no importance had been given to its implementation. All the vegetation had been cleared and burnt before impoundment (De Silva, 1985). It is strongly believed that the presence of vegetation has advantages in fisheries although there are difficulties in setting and removing fishing gear.

The presence of tree trunks and other obstacles prohibits the use of any dragging gear, and the most affected are the gill nets. The two widely distributed macrophytes which affect fiaheries in reservoirs are *Salvinia* and lotus. In some reservoirs such as Maduru Oya, presence of large amount of *Salvinia* has affected the fishery.

10. HARVESTING

The type of crafts and gear used in reservoir fisheries is the same throughout the country. The Government has taken steps to replace the traditional wooden canoes with fibre glass canoes through a subsidy scheme introduced in 1980. These canoes have a longer life span. No mechanized crafts are permitted in reservoirs. The average fish production from a fibre glass canoe is around 4 t/yr.

The mesh size of gill nets used in reservoirs ranges from 76 to 140 mm. Each boat carries 4 to 5 net lengths, each being 20 m long. The fishermen lay the nets in the evening and haul them in the morning. Use of beach seines is prohibited. The bottom conditions prevent the use of any bottom dragging nets. De Silva (1985) reported that in most of the reservoirs fishing effort has been on the increase over the last few years. The yield/craft/yr has shown a significant decrease in some of the reservoirs. He also observed that yield from the reservoirs increased during the rainy season.

In addition to gill net fishing, cast netting and hook and line fishing are applied.

According to Costa *et al.* (1988) the water beating technique (a modified gill net fishing method) to drive the fish towards nets, is also adopted by some gill net fishermen. They state that the efficiency of this water beating technique has been claimed to be more than the normal gill netting method and that it is more effective for fishes with restricted movements such as *O. niloticus*, *T. rendalli* and *E. suratensis*.

11. MARKETING

Fishermen sell their catches mainly to bicycle vendors and lorry traders who call at reservoirs. The vendors sell their purchases to local consumers travelling from house to house. Vendors usually pay the money at the time of buying from fishermen. In some areas a vendor buys fish from more than 5 fishermen. A significant number of vendors own scooters too. They transport fish to distant places and sell at wholesale prices to the people who own stalls in small towns. This method does not require any refrigeration facilities. In some areas excess fish is dried or smoked. The lorry traders distribute the fish among retailers in the cities.

The price of tilapia paid to fishermen varies from Rs.8/kg to 12/kg depending on the size, location and season. Price of common carp in some areas is around Rs.20 to 25/kg. Retail price of tilapia is around Rs.20 to 26/kg.

12. UTILIZATION OF OTHER FISH SPECIES

The possibility of developing a subsidiary fishery for small minor cyprinids such as Amplypharyngodon melattinus, Rasbora daniconius and B. chola, without affecting the existing gill net fishery, was suggested by Schiemer and Hofer (1983) and De Silva (1983,1985). Minor cyprinids move into deeper waters when they are mature and inhabit areas similar to those of adult O. mossambicus. A selective gill net fishery for such species could be operated without a harmful effect on the immature O. mossambicus. Sirisena and De Silva (1988) recommended the use of 20 mm or 30 mm mesh gill nets for exploitation of minor cyprinids. They also stated that introduction of a fishery for minor cyprinids could lead to doubling of the present yield. It is doubtful, however, that minor cyprinids could be used for human consumption, but they could be used for fish meal production. A well organized two-tier exploitation system could be developed to exploit the introduced species and minor cyprinids. De Silva (1985) has also suggested to initiate surveys using long-lining and small meshed gill nets to ascertain the extent of carnivores which are at present accidental or negligible in the commercial fish catches.

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